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ART. XXIX.—*On the Mineral Locality at Branchville, Connecticut:* Fourth Paper.* *Spodumene and the results of its Alteration*;† by GEORGE J. BRUSH and EDWARD S. DANA. (With Plate IV).

IN the present paper we give the results we have obtained in a study of the spodumene from Branchville, Conn., and of the various minerals derived from its alterations. It is, after the feldspars, mica and quartz, the most important of the original minerals of the locality, and occurs, though mostly in an altered condition, in very large quantities.

* For previous papers upon this subject see this Journal, III, xvi, 33, 114, 1878; xvii, 359, 1879; xviii, 45, 1879.

† An extended and valuable memoir upon "Spodumene and its alterations from the granite veins of Hampshire Co., Mass.," has been recently published by Mr. A. A. Julien in the Annals of the New York Academy of Sciences, Vol. i, No. x (see this Journal, xix, 237, March, 1880). It is proper that we should state here that most of the results of this paper, including every analysis, had been completed previous to the appearance of that of Mr. Julien, and when we had no further knowledge of its contents than is suggested by the preliminary notice of cymatolite published by him in this Journal for May, 1879 (xvii, 398). The fact, however, that Mr. Julien was engaged upon this investigation and had been at work upon it for several years was known to us, and we felt it only right that we should defer the publication of our article until his had appeared. It will be seen that our results, though arrived at independently and based upon material from a different source, in many cases confirm those of Mr. Julien, and this, as we believe, adds much to the interest of the whole subject. Our conclusions, however, differ essentially in some respects. We have found that cymatolite is not a true species, but only a mechanical mixture of albite and muscovite. This fact, taken with the presence of the analogous complex substance, β spodumene, makes it now possible to give a reasonably clear and thorough explanation of all the changes involved in this most interesting case of pseudomorphism.

A. Unaltered Spodumene.

The greater part of the unaltered spodumene occurs in confusedly crystalline masses, showing distinct cleavage, but seldom any approach to crystalline form. It is possible to obtain the mineral nearly pure, though somewhat intermingled with albite, in blocks weighing several hundred pounds. In this form the spodumene has a dull white color; it is in many cases somewhat discolored, and is only partially translucent; the cleavage surfaces are often coated with delicate dendrites of manganese oxide. The associated minerals, in addition to the albite and a little quartz and mica, are apatite, lithiophilite, columbite, garnet and uraninite, with various other uranium minerals formed from alteration.

In addition to this massive variety, the spodumene also occurs in an unaltered condition as nuclei of distinct pseudomorphous crystals. These crystals often occur of enormous size, imbedded for the most part in massive quartz, though sometimes extending into the albite. The nucleus of spodumene (see below and figures 1*a*, 5, 8, 14, Plate IV*) is in every case sharply separated from the altered mineral surrounding it, and its characters show that the crystals must originally have had rare beauty. One of the finest crystals that we have found thus far had, as imbedded in the quartz, a length of three feet, a width of eight inches and a thickness of two inches. The unaltered spodumene, of a fine amethystine color, made up about one-fourth of the whole, extending rather regularly through the middle of the crystal. Unfortunately, the spodumene was much rifted and fractured, so that its former transparency had, for the most part, disappeared. The exterior of the crystal consisted principally of β spodumene, with small quantities of cymatolite and albite. Another altered crystal was measured while imbedded in the quartz, of which a length of over *four feet* was exposed. It is not possible to extract these crystals entire, but many fragments have been obtained which have a width of over a foot across the prism and a thickness of two to four inches. In habit the crystals are much like those from Norwich, Massachusetts. They are generally broad or flat, through the development of the orthopinacoid, and comparatively thin; not unfrequently they are well terminated. Occasional stout crystals, having a square prismatic form, much like pyroxene, are also observed.

In the better specimens the spodumene is perfectly transparent, sometimes colorless, and again of a beautiful rose-pink or amethystine-purple color. It shows the prismatic cleavage with unusual perfection, and that of the clinopinacoid irregu-

* Figures 1 to 14 inclusive are to be found on the accompanying Plate, the other figures (15–20) are in the text.

larly. The angle of the prismatic cleavage—viz., 87° 13′—was obtained with great exactness.

Chemical composition.—An analysis of the transparent pink spodumene was made by Mr. S. L. Penfield with the following results. Specific gravity = 3·193.

	I.	II.	Mean.		Ratio.	
SiO_2	64·32	64·18	64·25		1·071	4
Al_2O_3	27·14	27·26	27·20	·262	·263	·98
Fe_2O_3	0·18	0·22	0·20	·001		
Li_2O	7·64	7·59	7·62	·254	·260	·97
Na_2O	0·39	0·39	0·39	·006		
K_2O	tr	tr	tr			
Ignition	0·24	0·24	0·24			
	99·91	99·88	99·90			

The ratio of $Li_2O : Al_2O_3 : SiO_2 = 1 : 1 : 4$; this corresponds to the oxygen ratio* of 1 : 3 : 8. The formula is then, neglecting the very small amount of soda,

$$Li_2Al_2Si_4O_{12}.$$

This result agrees exactly with that reached by Dœlter in his investigation of the composition of spodumene,† and with that of Julien.‡ It is to be noted, however, that the percentage of lithia here obtained is higher and that of soda lower than in any analyses previously published. For example, Dœlter found in the Norwich mineral 7·04 Li_2O, 1·10 Na_2O and 0·12 K_2O; in that from Brazil 7·09 Li_2O and 0·98 Na_2O. Julien obtained in the Goshen spodumene 6·89 Li_2O, 0·99 Na_2O, 1·45 K_2O; and in that from Chesterfield 6·99 Li_2O, 0·50 Na_2O, and 1·33 K_2O. Dœlter concludes for the Norwich mineral that the amount of lithia obtained is rather too small than too large, and attributes the soda present to incipient alteration. The correctness of this view seems to be proved by the analyses here published of the Branchville mineral, which certainly left nothing to be desired in regard to purity or freedom from alteration. The great tendency of spodumene to change by the assumption of potash or soda and loss of lithia will be made evident by what follows.

B. Alteration of Spodumene.

As the result of the alteration of the spodumene, we have found two substances which at first sight seem to be homogeneous, and each of which has a definite chemical composition, and which, notwithstanding, are only intimate mechanical mixtures of two species; one of these, called by us β spodumene, is made up of albite and a new lithia mineral to which

* This ratio was obtained by Brush from analyses of the Massachusetts mineral in 1850. Am. Jour. Sci., II, x, 370.

† Tschermak, Min. u. Petr. Mitth., i, 517, 1878. ‡ l. c., p. 325.

we have given the name *eucryptite;* and the other is cymatolite, an aggregate of albite and muscovite. We have also found the following independent minerals:—albite, microcline, muscovite, and killinite. The two complex substances and all of the last named minerals, except the mica, occur as distinct pseudomorphs, having the form of the spodumene. The mica, taken independently of its constant associate the albite, plays only a secondary part. In addition there are other pseudomorphs, of composite character, consisting, as Mr. Julien has well expressed it, "of vein granite."

We will first give the physical and chemical characters of the various minerals (including the two aggregates) taken separately, and then go on to describe more minutely the way in which they are associated together.

I. Products of the Alteration.

1. *β Spodumene.*

The substance which we have, for convenience, called *β* spodumene, since we do not regard it as deserving an independent name, seems to mark the first step in the alteration of the spodumene.

Physical characters.—It is a compact, apparently homogeneous mineral, having a rather indistinct fibrous to columnar structure, this being always at right angles to the adjoining surface of the original mineral. Hardness 5·5 to 6; specific gravity 2·644–2·649. Color white to milk white, and again slightly greenish-white; translucent. Fusibility=2·25.

Chemical composition.—Analyses of three independent specimens have been made by Mr. S. L. Penfield. Number 1 was taken from a crystal, part of which consisted of the transparent pink spodumene, described above, and the outer portion was this mineral (similar to fig. 5). The line of demarcation was perfectly sharp, so that the purity of the material analyzed cannot be questioned. The results of the analysis are as follows:—

No. 1, G.=2·649.	I.	II.	Mean.		Ratio.	
SiO_2	61·35	61·42	61·38		1·023	4
Al_2O_3	26·26	25·74	26·00	·253	·255	·99
Fe_2O_3	0·24	0·24	0·24	·002		
Li_2O	3·63	3·59	3·61	·120	·254	·99
Na_2O	8·32	8·25	8·29	·134		
K_2O	tr	tr	tr			
Ignition	0·46	0·46	0·46			
	100·26	99·70	99·98			

The second portion analyzed was from a fragment of a large and entirely altered crystal; its dimensions were 9 by 8 by $2\frac{1}{2}$ inches. It consisted mostly of cymatolite, and the *β* spodu-

mene had all the appearance of passing insensibly into it; a single fragment, across the prism, could be obtained made up of both minerals, the fibrous structure of the one being continued in the other (similar to fig. 1*b*). The analysis yielded:—

No. 2, G.=2·644.	I.	II.	Mean.		Ratio.	
SiO_2	61·46	61·57	61·51		1·025	4
Al_2O_3	not determined	26·56	26·56		·258	1
Li_2O	3·55	3·44	3·50	·117		
Na_2O	8·15	8·13	8·14	·131	·249	0·97
K_2O	0·15	0·15	0·15	·001		
Ignition	0·29	0·29	0·29			
		100·14	100·15			

The third portion was part of a smaller and well developed crystal, having the external prismatic form complete. It consisted in the interior of spodumene, then the β spodumene making up the greater part of the whole, and finally a thin crust of cymatolite. The specimen analyzed was, as far as the eye could detect, perfectly pure and homogeneous. The color was greenish-white and it was decidedly translucent. The analysis afforded:—

No. 3, G.=2·649.	I.	II.	Mean.		Ratio.	
SiO_2	61·78	61·64	61·71		1·028	4
Al_2O_3	26·57	26·69	26·63		·259	1
Li_2O		3·83	3·83	·128	·260	1
Na_2O		8·16	8·16	·132		
K_2O		tr	tr			
Ignition		0·21	0·21			
		100·53	100·54			

If the mean analyses of the three groups be compared, it will be found that they agree very closely with one another; in fact the agreement is as close as could be expected for three successive analyses made upon the same material. But, as will be seen from what has already been said, the three samples were entirely *independent*, being taken from different parts of the ledge and differing in manner of association; the agreement between them thus becomes very striking. The ratio obtained for each

$$\dot{R}_2O : R_2O_3 : SiO_2 = 1 : 1 : 4$$

is the same as that of spodumene, from which it differs only in this: that one-half of the lithium has been removed and its place (chemical equivalent) taken by sodium. The formula is then:—

$$(Li, Na)_2Al_2Si_4O_{12} = Li_2Al_2Si_4O_{12} + Na_2Al_2Si_4O_{12} \quad (1)$$

$$\text{or} = Li_2Al_2Si_2O_8 + Na_2Al_2Si_6O_{16} \quad (2)$$

It is shown below that the formula given in (2) is the correct one.

The facts stated thus far would seem to be sufficient to prove that the mineral was homogeneous and had a definite composi-

tion; there are, however, other facts which have an important bearing upon this point.

It was found by Mr. Penfield that, although the mineral gelatinizes with acid, it is not entirely decomposed. On the contrary, it is divided into two portions by the treatment with hydrochloric acid, viz:—a soluble portion (A), and an insoluble remainder (B), the latter including also the silica extracted from the soluble part. The results of three analyses gave

	A. Soluble in HCl.	B. Insoluble in HCl, with SiO_2 from A.
No. 1	(17·97)	82·03 = 100·
2	16·65	83·01 = 99·66
3	17·91	82·18 = 100·09

In the case of No. 2, complete analyses of both the soluble and insoluble portions were made; these were independent of the total analyses of the same sample already given. The method of analysis was, briefly, as follows:—A gram of the mineral was digested with HCl, evaporated to dryness, then moistened with HCl and a second time evaporated to dryness. After being again moistened with HCl the soluble portion, A above, was filtered off and the alumina and alkalies determined in it by the usual methods. The insoluble portion, which included the silica extracted from A, after being weighed, was boiled with Na_2CO_3 and (in the case of No. 3) with a little KOH. By this means the soluble silica of A was dissolved out and the insoluble remainder being weighed, the amount of the soluble silica was determined by the difference. Finally, the insoluble part was analyzed in full by the usual methods. The results of the analyses were as follows:

	No. 2.
B. Insoluble in HCl with silica of A	83·01
Insoluble remainder after treatment with soda	67·56
	15·45
A. Soluble in HCl (16·65), plus silica extracted by soda from B	32·10

The two parts, therefore, into which the original mineral is divided by hydrochloric acid, are:—

	No. 2.
A. Soluble portion	32·10
B. Insoluble portion	67·56
	99·66

The composition obtained for A was as follows:—

A. *Soluble portion.*

	No. 2.	Calculated to 100. No. 2.	Calculated from formula.
SiO_2	15·45	48·13	47·51
Al_2O_3	13·00	40·50	40·61
Li_2O	3·50	10·90	11·88
K_2O	0·15	0·47	----
	32·10	100·00	100·00

For the above analysis the ratio is, nearly :—

	SiO_2	:	Al_2O_3	:	Li_2O
No. 2	2	:	1	:	1

This corresponds to the formula, $Li_2Al_2Si_4O_9$, the percentage composition of which, given above, agrees well with the analysis.

The composition obtained for B was:—

B. *Insoluble portion.*

	No. 2.	Calculated to 100. No. 2.	Calculated from formula.
SiO_2	46·06	68·18	68·62
Al_2O_3	13·56	20·07	19·56
Na_2O	7·94	11·75	11·82
	67·56	100·00	100·00

The ratio calculated from the preceding analysis is:—

	SiO_2	:	Al_2O_3	:	Na_2O
No. 2	6·		1·07		1·00

This ratio is very closely that of *albite*, viz: 6 : 1 : 1, so that the formula for the insoluble portion is $Na_2Al_2Si_6O_{16}$.

An analysis was also made of sample No. 3, but the separation was a little less complete than of No. 2; the first digestion in acid left behind a very little of the soluble mineral, as shown by the presence of lithia in B, and then in the subsequent treatment of the insoluble part (in which also KOH was employed) there seemed to have been a slight decomposition of the albite. The results, although for the reason given hardly worth putting on record, were satisfactory in this, that they confirmed those of No. 2.

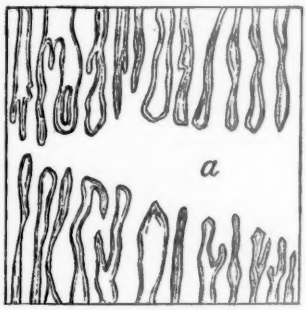
The point thus far established may be stated as follows: A chemical examination proves that the substance, called provisionally β spodumene, is not a distinct species, but only a very uniform mixture of two minerals; one of these, called by us *eucryptite*, dissolves with gelatinization in hydrochloric acid, and has the composition, $Li_2Al_2Si_2O_8$; the other, not attacked by acid, is *albite*, $Na_2Al_2Si_6O_{16}$. The true expression of the chemical composition of the substance is, therefore, seen to be that (2) given above. That the mixture is truly mechanical, and not a molecular one broken up by the acid (if that were possible), is proved by this significant fact: the insoluble residue (B above), left after the digestion in sodium carbonate, was in one case examined under the microscope, and found to be *crystalline*, and to have the peculiar semi-fibrous structure belonging to the pseudomorphous albite, as described below.

The microscopic examination of thin sections of β spodumene confirms the results reached from the chemical side as to

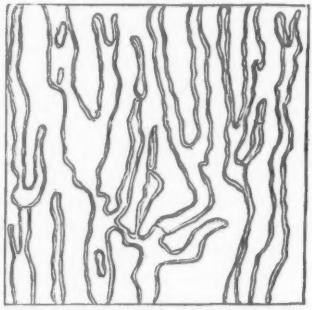
the complex nature of the substance, and gives, in addition, a very satisfactory determination of the crystalline character of the new lithia mineral. A series of thin sections were prepared, some parallel to the fibrous structure, that is at right angles to the original mineral (spodumene), and others transverse to the fibers and consequently parallel to the original prism. The sections parallel to the fibers, when examined under the microscope, seemed at first sight to give no proof of want of homogeneity. The fibers, seemingly of rounded form, and though in general parallel yet quite wavy in outline, are packed so closely together that the question of the presence or absence of any substance between the fibers and enclosing them could not be answered; the whole gave the effect of aggregate polarization. The above statement is true for the greater portion of each of the slides—the result thus far was negative.

Occasional irregularities, however, in the usually parallel fibrous structure, which may not inaptly be compared in appearance to the grain of wood-fiber in the neighborhood of a knot, as seen in a smooth board, gave better results. The fibers in such cases are much curved and irregular in outline, and so separated from one another that they are seen to be merely enclosures in a surrounding matrix. In other cases, this enclosing material forms open spots, where the structure (in polarized light) is found to be that of ordinary albite, and into this the needle-like fibers of the other mineral project (this is illustrated in fig. 15, a = albite). Still again, on the edges of the sections

15.



16.



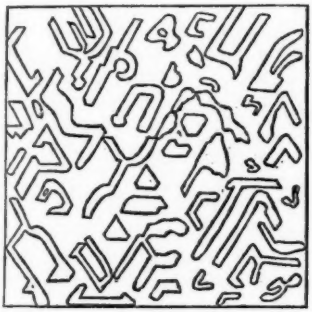
where a degree of thinness impossible for the whole slide is sometimes attained, a similar satisfactory result is reached. The fibers in such cases are distinctly seen, independently of each other and of the enclosing albite. They are generally nearly straight and parallel, but not infrequently the shape is more or less irregular; branching forms recalling some kind of coralline

structure are common. The latter forms are shown in fig. 16; the fibers here are much more irregular and coarser than is generally true. (Compare also fig. 19.) The fibers are apparently rounded but the outlines are usually indistinct, and the form can be made out only by repeatedly changing the focus of the microscope. The explanation of all these irregularities in outline is given by the result obtained on examining the sections cut transverse to the fibers. Several additional facts were brought out in the study of the sections now described. It was found that, when examined between crossed Nicols, the extinction of the light took place *parallel* to the length of the fibers; moreover, the fibers have not infrequently a transverse fracture, probably indicating cleavage. The form of the terminations of the needles could not be certainly observed. In cases like those above described (fig. 15), the extremities seem to be given entire, but no absolute assertion can be made in regard to them. In many cases, probably the majority, they taper out gradually to a fine point, while in others they seem to be terminated by a low pyramid.

The examination of the other set of sections, cut across the fibers, was even more satisfactory and conclusive. The appearance in polarized light, as the plate is revolved on the stage of the microscope, is at once striking and beautiful. The section as a whole is divided into irregular patches (albite), changing from dark to light and the reverse with the revolution, giving the whole a strangely mottled look. Distributed closely and

17.

18.



uniformly through this matrix are seen also minute areas of another substance, sometimes curved but generally bent at an angle of 60° or 120°; they are *unchanged* by the revolution between the crossed Nicols. The effect will be best appreciated from the accompanying sketches (figs. 17, 18). When a high power is employed (say 600 diam.) and the attention is confined to a small portion at once, it is seen that these narrow bands, which

in a cursory glance under a low power seem to be quite irregular in form, are, on the contrary, approximately in parallel position. The solid portions are triangular or hexagonal in outline, and the bands are bent at angles of 60° and 120°, sometimes so as to form complete rings;—they are all more or less rounded. In short, the structure is that of the most regular pegmatite or "graphic granite," and the explanation is the same. These regular forms, like those of the quartz in the feldspar in the other case, are due to the restricted crystallization in the albite of the new mineral in question. They mark the mineral as belonging to the hexagonal system, and the result of the optical examination both parallel and transverse to the fibers confirms this conclusion.

Taking the section as a whole, there are portions in which the directions of the new mineral are quite irregular, but for the greater part there is an obvious tendency toward regularity, sometimes leading to most perfect forms. As would be expected, the axial directions (60°) change at small distances, so that a given set of directions belongs only to a limited area; this is obviously determined by the enclosing albite.

We are now able to connect the results of the microscopic examination with those of the earlier chemical investigation. The enclosing material in which the fibers lie is the *albite;* this is proved indeed by what has been stated, and moreover by the fact that it, whenever distinctly separate, has the same structure as in undoubted cases of the same pseudomorphous material; it is also shown by the examination of the insoluble portion alluded to before, for in this the fibers have been removed and the matrix left unattacked. The enclosed mineral is that which with the albite makes up the β spodumene, having the composition $Li_2Al_2Si_2O_6$.

In view of the fact that this lithia-bearing mineral is thoroughly defined, as well crystallographically as chemically, and considering, moreover, the important part it plays in the history of the spodumene, we feel obliged to give it a distinctive name. We call it *eucryptite*, from εὖ well, and κρυπτός concealed.

EUCRYPTITE crystallizes in the hexagonal system, with probably basal cleavage. Its specific gravity, calculated from that of β spodumene, 2·647 and that of the pseudomorphous albite 2·637, is 2·667. It gelatinizes with hydrochloric acid and fuses easily. It is a unisilicate, and its chemical composition is expressed by the formula $Li_2Al_2Si_2O_6$=silica 47·51, alumina 40·61, lithia 11·88=100·00. Its mineralogical relations are not very certain; still, in form, and essentially in composition, it is analogous to nephelite. It also might be viewed as a lithia-anorthite, it having the same ratio as anorthite; though it is different crystallographically. On the other

hand, the fact that it changes so readily into muscovite, and has the same ratio as the normal varieties of that species, might seem to place it near it; but it certainly has no micaceous structure. The true lithia mica (lepidolite) has a very different composition.

2. *Cymatolite.*

The name cymatolite was given in 1867 by Prof. Shepard to a mineral found at Goshen and Norwich, Mass., a result of the decomposition of spodumene. The analysis given by him left the composition of the supposed new mineral in question, and this doubt was not removed by a subsequent analysis by Mr. B. S. Burton. Mr. Julien gives in his paper several analyses of cymatolite which agree well together and which correspond to a simple chemical formula. In our earlier investigations we assumed it to be an established point that the species was a good one and had a definite composition. This assumption was confirmed by two closely agreeing analyses (given below) made upon the Branchville material. Further study, however, which was made necessary by the results reached in the case of β spodumene—for the cymatolite is directly derived from the β spodumene—has convinced us that the supposed species is only a remarkably uniform and intimate *mechanical mixture of muscovite and albite.* We shall, however, throughout this paper retain the name cymatolite as a convenient way of designating this interesting compound substance, and shall describe it first as if it were a true species.

The *physical* characters of the cymatolite of Branchville are as follows:—It has a distinct fibrous structure, sometimes straight but more generally wavy. It is also at times confusedly fibrous and again scaly. The specific gravity = 2·692–2·699. The color is generally white, but it is often slightly discolored and occasionally it has a faint pink hue.

As has been stated on p. 258, the crystals of spodumene, which have been altered to cymatolite, are numerous and often very large. The way in which the fibrous structure is developed is seen in fig. 2, which is a section across the prism. It is usually true, as seen here, that the direction of the fibers at the edge is at right angles to the bounding surface. In the interior the structure is more irregular and the fibers interlace in an intricate manner, giving sometimes a feather-like appearance. Usually all trace of the original prismatic structure and cleavage of the spodumene has disappeared. In rare cases, however, in the interior of a crystal this longitudinal structure is still apparent, although the direction of the fibers remains transverse. (Compare also other figures in the Plate, in which c = cymatolite.)

Two analyses of cymatolite have been made by Mr. Penfield. Number 1 was made from a portion of an entirely altered crystal; it was perfectly white and apparently free from any impurities. The results are as follows:—

No. 1, G.=2·692.	I.	II.	III.	Mean.		Ratio.	
SiO_2	59·38	----	----	59·38		·989	4
Al_2O_3	26·67	----	----	26·67		·259	1·05
CaO	0·62	----	----	0·62	·011		
Na_2O	----	7·66	7·70	7·68	·124	·283	1·13
K_2O	----	3·53	3·49	3·51	·037		
H_2O	2·01	----	----	2·01	·111		
				99·87			

The second analysis was made on the pure mineral associated on the same crystal, which afforded sample 2 of β spodumene. The results afforded are, as follows:—

No. 2, G.=2·699.	I.	II.	Mean.		Ratio.	
SiO_2	60·61	60·49	60·55		1·009	4
Al_2O_3	26·37	26·39	26·38		·256	1·016
MnO	0·08	0·06	0·07			
Na_2O	8·08	8·16	8·12	·131		
K_2O	3·33	3·35	3·34	·035	·263	1·044
Li_2O	0·17	0·17	0·17	·006		
H_2O	1·65	1·66	1·65	·091		
	100·29	100·28	100·28			

The agreement between these two analyses is as close as could be expected; the ratio obtained from No. 2 is nearly

$$\dot{R}_2O : Al_2O_3 : SiO_2 = 1 : 1 : 4.$$

This is the same ratio as that obtained for spodumene and β spodumene. The formula is therefore

$$(Na, K, H)_2Al_2Si_4O_{12} = (K, H)_2Al_2Si_2O_8 + Na_2Al_2Si_6O_{16}$$

Since the cymatolite is certainly derived from the β spodumene, while the latter substance has been proved to be a mixture of albite and what—as was shown—has the composition of a lithia muscovite, the fact that the formula of cymatolite can be written as a compound of one molecule *muscovite* and one molecule *albite* is significant. Were no other facts at hand the conclusion that cymatolite also must be a mechanical mixture could hardly be questioned. The facts, however, are in themselves sufficient to prove this, independent of any other considerations. It may be mentioned that the chemical method of attacking the problem, employed in the case of the β spodumene, is not here applicable, since the muscovite is not decomposed by hydrochloric acid. A preliminary examination was made with sulphuric acid, which resulted in showing that the cymatolite was attacked by it, as was the mica of the locality, while the albite was barely so. This method was, however, not carried further, for the microscope gave all the solution that could be desired.

A considerable number of sections of cymatolite, both in its purest normal varieties, and in its transition forms from β spodumene on the one hand and to albite on the other, were examined. The result not only proved the fact of the mixture of muscovite and albite, but also gave the explanation for the remarkable uniformity of the analyses, for in most cases the mixture is in the highest degree intimate. A section of cymatolite like that represented in fig. 1*c* (Plate), when examined in polarized light, is found to consist of long, slender, somewhat curved fibers, giving very brilliant colors and showing the characteristic structure of mica, and between them grayish portions of albite. In some cases the fibers of mica are so close together that the albite is invisible, but in others they spread out divergent and then the background of the other mineral is clearly seen. Still again, the mica needles are few and run out in brilliant lines over a broad surface of albite.

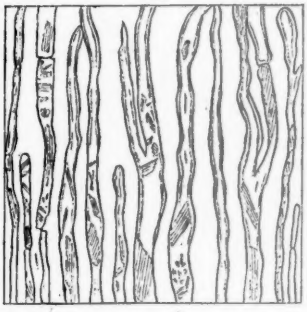
The sections increase in beauty with the irregularity of the structure of the cymatolite. For example, two sections were made from the crystal represented in fig. 2 (Plate). One of these was, like the figure, transverse, and the other was vertical, and showed something of the prismatic structure of the original spodumene. All the details of the structure came out most clearly in the sections in polarized light. The feather-like structure was particularly distinct and beautiful: a deeply colored rib of mica, and from this diverging regularly on both sides the narrow fibers of the same mineral, the albite between them becoming more and more distinct as their distance apart increased. Other sections were examined of the scaly varieties of cymatolite, where the mica scales were parallel to the surface. In these the albite had the mottled appearance in polarized light, mentioned under β spodumene, and the mica was scattered very uniformly as brilliantly colored scales through it. Other sections transverse to the fibers, in the distinctly fibrous kinds, gave somewhat different effects. Many details could be added, but enough has been said to make the character of the observations apparent on which the statement as to the compound nature of cymatolite is based. The mica and albite are always distinct from one another. In some cases they both appear in larger masses having segregated together in the process of alteration. More is said about this later.

The only foreign mineral observed in the slides was one which occurs in hexagonal prisms, and can hardly be anything but *apatite*, as it agrees optically and crystallographically with that species. It is seen scattered through the cymatolite sometimes rather abundantly, occasionally also in the β spodumene, it is, however, not for a moment to be confounded with eucryp-

tite. The presence of apatite would explain the lime found in analysis 1 of cymatolite.

Certain of the sections which show the transition from β spodumene to cymatolite are most interesting and instructive. While in much of the cymatolite there seems to have been a tendency to the partial separation of the mica and albite, there are other specimens in which the two are as intimately mixed as the eucryptite and albite in the β spodumene. In cases like those last named, the structure of the cymatolite is exactly that of the β spodumene, only that the rounded fibers of eucryptite have been replaced by the thin elongated scales of mica, proving that the one has been formed from the other. In still other cases we may pass on the same slide from normal cymatolite on the one side to normal β spodumene on the other. Between them is a zone where the two substances shade off into one another, in other words where the change of the eucryptite is only partial. This will be understood from fig. 19. As here seen, some of the fibers are apparently unchanged, while others are partly altered, the last containing many minute scales of mica, often packed closely together. These small scales are irregularly situated, often across the original fiber of eucryptite: the direction can always be observed both by the cleavage line and too by the direction of the extinction of the light between crossed Nicols. Where the process has been completed, however, the scale of mica is generally parallel to the line of the original eucryptite. The eucryptite fibers along this intermediate zone, even when mica scales are not visible, have generally lost their smoothness of outline, and sometimes have separated into lines of minute, irregular, transparent granules.

19.



The transition of β spodumene into cymatolite can also often be seen by the unaided eye, along the line of contact. In such cases the silvery lines of mica, though the scales are too minute to be distinguished, can be seen shooting up into the compact β spodumene.

3. *Albite.*

The albite, which occurs pseudomorphous after spodumene, appears in several rather distinct varieties. It is sometimes finely granular, showing no crystalline structure. Again it has a fibrous structure, similar to that of β spodumene and cymatolite, the fibers transverse to the prism. Still again it is

found forming parts of altered crystals, in which it has the curved and wavy laminated structure which is characteristic of the mineral that makes up so large a part of the vein; it also appears as rosettes implanted on the surfaces of many crystals, evidently owing its origin in such cases to the alteration.

An analysis of the fibrous variety of the species afforded Mr. Penfield the following results:—

G. = 2·637.	I.	II.	Mean.	Ratio.	
SiO_2	67·61	67·59	67·60	1·127	6·
Al_2O_3	20·07	20·11	20·09	1·195	1·03
MgO	·16	·14	·15	·004	
Na_2O	11·71	11·66	11·69	·188 ·193	1·02
K_2O	·11	·11	.11	·001	
Ignition	·14	·14	·14		
	99·80	99·75	99·78		

This analysis corresponds closely to the formula $Na_2Al_2Si_6O_{16}$, or that of albite.

The occurrence of albite pseudomorphs after spodumene is mentioned by Mr. Julien, but among the Massachusetts specimens they seem to play a comparatively unimportant part. Mr. Julien speaks of the albite as mixed with a little muscovite and quartz, and states that these pseudomorphs are "a mere variety" of the coarse agglomerates of quartz, feldspar and mica, which he calls pseudomorphs of *vein granite*.

At the Branchville locality the albite as an independent mineral occupies a more common and perhaps more interesting place among the products of the alteration of the original spodumene.

The fibrous albite, of which the above analysis was made, formed the whole of a perfectly distinct crystal. A section was made of it and examined microscopically. It was found to be essentially pure, with only traces of mica (note the potash in the analysis). The structure was rather indistinctly fibrous and it was most interesting to note that its appearance was very closely that of the albite with the mica in cymatolite, as too with eucryptite in β spodumene. A number of the groups of fibers were found to consist of two parts optically, and the angle between the extinction of the light for them was from 10°–11°. As this is the angle for albite twins examined parallel to the basal plane, the agreement can hardly be accidental, and is a point of some interest.

A number of other sections of what we have called albite were also examined. The result proves that pure albite is rather rare, and that most of the granular albite in the crystals contains a considerable quantity of mica, and hence verges toward cymatolite. This qualification is to be remembered in examining the plate. In many cases the albite is found to be in broad plates characteristically twinned, and with them are

found scales of mica, large too as compared with those in normal cymatolite.

4. *Muscovite.*

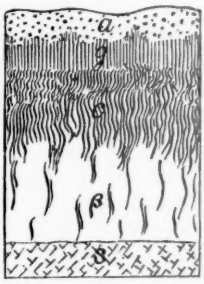
As a distinct mineral, independent of its usual associate the albite, the potash-mica, muscovite, plays an unimportant part among the spodumene pseudomorphs at Branchville. It occurs very commonly in thin scales coating fracture-surfaces in the interior of the altered crystals. It is also found in small segregated masses, or as scattered plates imbedded in the mass of the crystal itself. It occurs in this way more particularly in the complex pseudomorphs where the feldspars (albite and microcline) are also present in distinct masses. Its presence is indicated in figs. 6 and 8 (Plate, g=mica). This mica is commonly of a light greenish-yellow color and has a greasy luster; in some cases though more rarely it is pink in color, but is not a lithia-mica. It was not found possible to obtain enough pure material for an analysis.

The occurrence of the mica with the albite, forming the cymatolite, has already been described under that head. The analyses of the cymatolite show that the mica has the formula of normal muscovite, viz: $(K, H)_2Al_2Si_2O_8$. Taking the ratio of $K_2O : H_2O = 1 : 3$, corresponding approximately to analysis 2, the calculated composition of this muscovite is:—

SiO_2	46·23
Al_2O_3	39·52
K_2O	9·35
H_2O	5·20
	100·00

The complex nature of cymatolite having once been established, it is easy to find many specimens in which the mica and albite are so distinct that their independent existence can be proved by the unaided eye. The occurrence of albite containing small quantities of mica has been mentioned. Conversely, we find specimens in which the mica is more or less completely separated from the albite. Fig. 20 shows a part of a section across a crystal, with the nucleus of spodumene (s), then β spodumene (β), next cymatolite (c) graduating into pure and soft silvery mica (g), and finally a coating of albite (a). Such a case shows the extent to which the segregation of the constituents of the cymatolite can go on.

20.



In the Massachusetts specimens, the mica, as an independent mineral, is, according to Mr. Julien, much more abundant. We quote, on a following page, a remark of his on this point.

5. *Microcline.*

A second potash mineral, arising from the alteration of the spodumene, is a potash feldspar having the composition and optical character of microcline. This is a much rarer occurrence than that of the albite pseudomorphs. The microcline, where it occurs alone, which is seldom, has a fine granular structure, showing no cleavage whatever. The color is yellow, and under the microscope it is resolved into independent grains having the characteristic appearance of microcline in polarized light. In the best specimen observed, the crystalline planes, both prismatic and terminal, are perfectly distinct, but nothing was left of the original mineral. This pseudomorph consisted, for the most part, of the potash feldspar, but a small portion of one side was soda feldspar (or albite). The relation of these two minerals is shown in fig. 10, a case in which the albite is present in much larger quantities than in that described, it making up about half the crystal.

The composition of the yellow granular feldspar is shown by the following analysis by Mr. Penfield:—

G. = 2·548.	I.	II.	Mean.	Ratio.		
SiO_2	64·55		64·55	·1·076	6·	
Al_2O_3	19·70		19·70	·191	1·07	
K_2O	15·66	15·59	15·62	·166	·176	·98
Na_2O	0·53	0·64	0·58	·010		
Ignition	0·12	0·12	0·12			
			100·57			

It will be seen that the above analysis corresponds very closely with the normal composition of microcline, $K_2Al_2Si_6O_{16}$.

Figures 3 and 4 show further the manner in which the potash feldspar is contained in the interior of the soda feldspar, both forming part of perfectly distinct pseudomorphous crystals of spodumene. In addition to this method of occurrence, the microcline is also observed in broad cleavage plates forming sometimes almost entire crystals of the original mineral. Here, too, it is commonly associated with albite, as shown in figs. 11 and 13. One most interesting and significant fact in connection with this is that the separate fragments of microcline scattered through a single crystal at different points, though sometimes several inches apart, are uniformly in *parallel position.* The angles of the cleavages of the microcline differ in different specimens, so that their position seems to have no definite relation to the axes of the spodumene crystals.

It is worth while to call attention here to the fact that the potash feldspar, microcline, occurs in very large quantities at this locality. Several hundreds of tons have already been taken out by the Messrs. Smith for use in making porcelain. The

feldspar is obtained in cleavage masses as large as can be handled, and nearly pure; a single continuous cleavage surface *ten feet long* has been observed in the ledge.

6. *Killinite.*

Killinite is a hydrous silicate of aluminum and potassium ordinarily included among the pinite group of minerals. It was first described from Killiney Bay, Ireland, and a series of analyses is published in the Mineralogy of Greg and Lettsom. It was described as occurring in granite associated with spodumene, and has its cleavage. The same mineral is described by Mr. Julien as occurring at Chesterfield, Mass. Our results, which we give here, are for the most part identical with his.

The killinite from Branchville is sometimes compact and structureless, but more generally it has an indistinct fibrous structure parallel to the prism of the original mineral. Many specimens show distinctly the cleavages of the original spodumene. The color ranges through various shades of green, from light bluish-green to oil-green and dark grass-green.

Two analyses, on independent material, have been made for us; the first, number 1, is by Mr. S. L. Penfield, of the prismatic variety; and the other, number 2, is by Mr. F. P. Dewey, of the compact variety.

	No. 1.	No. 2.
SiO_2	48·93	53·47
Al_2O_3	34·72	32·36
Fe_2O_3	0·54	0·79
FeO	0·33	0·42
MnO	0·64	0·72
CaO	----	0·17
K_2O	9·64	7·68
Na_2O	0·35	0·44
Li_2O	----	0·04
H_2O	5·04	4·07
	100·19	100·16

The two analyses show a rather wide variation in composition between the material analyzed in the two cases. If, moreover, the analyses referred to above as published by Greg and Lettsom be compared together, and with that of Mr. Julien from Chesterfield Hollow and those here given, it will be seen that they vary between quite wide limits. It cannot be doubted, however, that essentially the same material was under examination in the several cases, and that the difference noted is probably due to a want of homogeneity.

Killinite gives water in the closed tube. B. B. glows and fuses at about 5 to a white enamel. Not decomposed by hydrochloric acid.

Several sections of killinite were examined in the microscope. The parallel fibrous structure is there clearly seen and

in addition there appear to be scales inclined at equal angles in opposite directions on either side of each parallel line. They exert a considerable action on polarized light. Most of the specimens are of so fine a texture as not to allow of satisfactory resolution. One section, however, which was somewhat coarser, seems to offer an explanation. This one appeared to consist mostly of minute scales having all the appearance of *mica*. These scales were strikingly similar to those of unquestioned character formed from the alteration of eucryptite and illustrated by fig. 19. There seems to be but little doubt that this is the true resolution of the mineral. In addition to these scales, there are small portions which do not polarize light, which may be amorphous silica, and occasional other particles less easily defined.

The idea of a relation, between the minerals of the pinite group and those potash micas which yield water on analysis, is not a new one, but was long since advanced. It is recognized by Professor J. D. Dana, in the 5th edition of his System of Mineralogy (1868), p. 447.

If analysis 1 of killinite be compared with the composition of muscovite on p. 272, and also with the analyses of muscovite in Dana's Mineralogy, 5th edition, the correspondence will be at once recognized. The variation of analysis 2 of killinite would be explained by supposing the presence of several per cent of free silica; the correspondence would then be quite close. Moreover, the observations with the microscope have already independently led to the suggestion of the probable presence of amorphous silica. In view of the part played by mica in the alteration of the spodumene the suggestion here made certainly seems plausible, although the want of perfect homogeneity in the killinite makes it impossible to give it a definite formula.

7. *Pseudomorphs of Vein-granite.*

We employ the same term, as Mr. Julien, to describe certain pseudomorphous crystals of spodumene, which consist of a more or less coarse agglomeration of feldspar (albite and microcline), and mica. In such cases, which seem to be rarer at Branchville than at Chesterfield, the constituent minerals are well developed and have the same character as in the vein as a whole. The feldspar, for example, is not granular and without apparent cleavage, as is generally true of the special cases before described, but occurs in rather broad cleavage fragments. The surfaces of these crystals are very rough, often covered with rosettes of albite, and yet the general form of the original spodumene can always be distinctly seen. It is to be noted that quartz is almost entirely absent in these com-

plex pseudomorphs, in which they differ essentially from the Chesterfield specimens.

II. Relation in method of occurrence between the various minerals produced by the alteration of the spodumene.

The individual characters of the several minerals produced from the change of the spodumene have already been given, and something has been said as to their mutual relations; it seems best, however, to add a few more general remarks as to their method of occurrence.

Spodumene and β Spodumene.—The way in which these two minerals occur together will be better understood from fig. 5. As indicated in this case, the alteration product, β spodumene, forms a more or less thick crust about the original mineral, and also penetrates in bands which follow the directions of the cleavage surfaces, and which are sometimes mere lines and again have considerable thickness. It is worthy of note, that in all cases the line of separation between the two is perfectly distinct, and the spodumene so associated seldom shows at most more than a trace of alteration. The direction of the fibers is, as stated, transverse to the neighboring surface of spodumene in each case, though in some cases it is so compact as to show little structure.

In one very interesting case the crystal consisted in part of β spodumene and in part of the original mineral, but the latter though unchanged in other respects had already taken the transverse structure of the former, and the longitudinal prismatic structure was nearly obliterated. This must evidently be an early step in the process of change.

β Spodumene and Cymatolite.—Many crystals and fragments of crystals which do not show a trace of spodumene exhibit these two minerals in very distinct relations. The aspect of them is such as to leave no doubt that the first passes gradually into the other, the blades of cymatolite interlacing with the less distinct fibers of β spodumene wherever the two come in contact (see fig. 1*b*). The appearance, however, is always that of two distinct substances, even when the line of union is examined under the microscope. It is consequently necessary to conclude that while the alteration went on gradually there was chemically an abrupt change from the one substance to the other. As already remarked, the analysis 2 of β spodumene was made of a portion, which, though apparently pure, immediately adjoined the cymatolite, and the result is identical with the others, where the idea of a regular gradation could not be suggested. Many of the large crystals of cymatolite, when examined carefully, show a trace of the other mineral, and we are forced to believe that at least for this locality it always preceded it.

Spodumene, β Spodumene and Cymatolite.—It only remains to speak of the cases in which all three of the minerals named occur together in the same crystal. Many instances could be given, but it will be sufficient to describe a single striking case. In figs. 1*a*, 1*b*, 1*c*, there are represented three sections across the same crystal. This crystal had a length of 15 inches, a width of 4½, and was 1 inch in thickness; it was well terminated at one extremity. The sections, taken in order from the terminated end down, divide the crystal into three approximately equal parts. No. 1 (fig. 1*a*) shows the β spodumene (β) forming the mass of the crystal, with original spodumene (*s*) as a band on the lower surface, and the cymatolite (*c*) as a thin coating more or less continuous around the whole. No. 2. (fig. 1*b*) shows no spodumene, but the β spodumene forms the greater part, though the cymatolite has increased much beyond the first section. No. 3 (fig. 1*c*) shows only the cymatolite.

Figure 5, referred to above, shows all the three minerals, though the cymatolite is only sparingly present, and that on the edges. In figures 8 and 14 the spodumene forms a few points and small isolated portions having surfaces parallel to the cleavage. It is surrounded by β spodumene and cymatolite, the latter radiating out from the centers of spodumene. Crystals, in which only spodumene and cymatolite are present, are rare. In fig. 14 a single narrow band is shown which is still β spodumene, while all the rest is changed to cymatolite and albite.

Albite and Cymatolite.—The albite, as has already been remarked, is a common mineral among these pseudomorphs. In some cases it makes up almost the entire crystal, and again it is present only in small isolated portions. The commonest form is that which is very finely granular, although the fibrous form is not rare. It is to be remembered, however, that between the normal cymatolite (1 mol. albite + 1 mol. muscovite) and the pure albite on the one hand, and the pure muscovite on the other, there are many gradations.

Figure 3 is a vertical section of a portion of a crystal, the exterior of which is fibrous cymatolite (*c*), and the interior granular albite (*a*) with some bands of microcline (*m*). Fig. 7 is a section across a large crystal in which the two minerals are similarly disposed. Fig. 10 shows the albite and microcline, as also 11 and 13. Figs. 6, 8, 12, 14 show the way in which the granular albite is intermixed with the other species which have been mentioned. In still other cases, the albite is in broad curved plates, which would seem to have nothing of a pseudomorphous character except that the outlines of the spodumene crystals, of which they form a greater or less part, are still distinct.

Occurrence of Killinite and Cymatolite.—In many of the massive specimens, the spodumene is changed in part to killinite and in part to cymatolite, the two minerals being intimately associated with each other. This association is illustrated by fig. 9, in which *c* is the fibrous cymatolite and *k* the killinite. The latter makes up the mass of the specimen, and the cymatolite, with its usual transverse fibrous structure, is in thin bands following nearly the original cleavage lines.

It is the confusedly massive variety of the spodumene which has furnished nearly all of the killinite. In the distinct crystals it rarely appears, though here it is sometimes seen, as indicated by fig. 12, as a more or less irregular surface covering.

III. Genetic relation between the original Spodumene and the various products of its alteration.

The general character of the process of alteration, by which the spodumene was changed into the various products already described, was, in a word, as follows:—it consisted essentially in the substitution of sodium and potassium for the original alkali lithium. The interesting facts, that have been detailed, in regard to the compound nature of the substances called β spodumene and cymatolite, taken in connection with the occurrence of the two feldspars and the muscovite, make the whole process tolerably clear and simple. The fact that two molecules of spodumene would, with a change in alkalies, yield one molecule of muscovite and one of albite, was clearly brought out by Mr. Julien; and he uses it to explain the occurrence of the complex pseudomorphs consisting of distinct individuals of albite and muscovite. The study of the specimens from Branchville enables us to extend and complete this explanation.

The relations of the various minerals involved in the change are presented in the following table, showing what may be derived from the spodumene, assuming the change in alkalies to take place.

$$2\underset{\text{Spodumene.}}{[Li_2Al_2Si_4O_{12}]} = \underset{\text{Eucryptite.}}{[Li_2Al_2Si_2O_8} + \underset{\text{Albite.}}{Na_2Al_2Si_6O_{16}}], \beta \text{ Spodumene.} \quad (1)$$

$$= \underset{\text{Muscovite.}}{[(K, H)_2Al_2Si_2O_8} + \underset{\text{Albite.}}{Na_2Al_2Si_6O_{16}}], \text{ Cymatolite.} \quad (2)$$

$$= \underset{\text{Muscovite.}}{(K, H)_2Al_2Si_2O_8} + \begin{cases} Na_2Al_2Si_6O_{16}, \text{ Albite.} \\ \text{or } K_2Al_2Si_6O_{16}, \text{ Microcline.} \end{cases} \quad (3)$$

The first step in the process of alteration was the formation of the β spodumene, by the substitution of sodium for one-half the lithium and the breaking up of the original spodumene, so as to form equal parts molecularly of *albite* and the new mineral which we have called *eucryptite*. The true nature of this second mineral has already been detailed. It would seem to be a

comparatively unstable compound, since it changes so readily to muscovite.

The second step in the alteration was the formation of cymatolite out of β spodumene; this change consisting in the substitution of potassium (and hydrogen) for the remaining equivalent of lithium in eucryptite, and the consequent formation of muscovite. The result is a compound, in equal molecular proportions, of *muscovite* and *albite*. It is certainly most striking that this compound substance, as derived from different localities, should be of so uniform chemical character. The explanation for this is to be found in the nature of the chemical process by which the alteration was brought about, the reaction going on uniformly through the mass, without, in the majority of cases, any distinct segregation of the two constituents formed. The change to β spodumene must have been produced by the action of a soda solution, and the subsequent change to cymatolite by that of a solution containing potash.

We have now to speak of the pseudomorphs in which the resulting minerals, mica and feldspar, appear in distinct form, and not as almost irresolvable aggregates. It was first remarked in regard to the cymatolite that in its usual varieties the mixture between the muscovite and albite was an extremely close and uniform one. This is ordinarily the case with respect to the normal material, as is exhibited in hundreds of specimens. There are others, however, of which this is not true, but where the silvery luster due to the mica is more or less absent, and the substance approximates in character to pure albite; and, on the contrary, there are others where the albite is nearly absent and the mica is nearly pure (see fig. 20). The conclusion to which these facts have led us is that there are many gradual transition cases between the normal cymatolite and the pure albite and muscovite, that is, cases, where there has been a decided separation and segregation of these two minerals. These cases, however, require no especial explanation, for that the conditions should be such as to lead occasionally to such segregations was to have been expected. It is rather remarkable that they are comparatively rare, and that normal cymatolite is the rule.

The scheme, presented above, obviously requires that the muscovite and albite should be formed in equal parts molecularly, and by weight in the ratio of 1 : 2 nearly. The question now arises, independently, as to the almost entire absence of mica not infrequently observed in connection with large masses of albite. It appears, to be sure, in separate form as a scaly covering of fracture-surfaces through the altered crystals, and occasionally in small segregated masses, but the amount so observed is much smaller than the equation requires.

We are obliged to conclude that either the muscovite, if formed at the same time with the albite, has entirely disappeared, or else that the method of formation of the albite was sometimes different from that previously explained. It can hardly be questioned that in the cases mentioned it must have been formed independently of its associate, the muscovite. Where the albite has a distinct fibrous structure it must have been formed from the β spodumene (compare also figs. 8 and 12). The albite was probably made from this by the action of a solution of sodium silicate changing the remaining lithium of the eucryptite to sodium and introducing two molecules of silica. It may also have been formed immediately from the spodumene, as expressed in the following equation:

$$\underset{\text{Spodumene.}}{Li_2Al_2Si_4O_{12}} + 2SiO_2 = \underset{\text{Albite.}}{Na_2Al_2Si_6O_{16}}. \qquad (4)$$

Besides the albite pseudomorphs, there are also those consisting of the potash-feldspar, microcline, which require explanation. In regard to them, as has already been stated, there are the cases where the granular microcline is enclosed in albite, again others where it forms substantially the whole crystal, and still others where it is scattered through in large cleavage masses. Reference to formula (3) above shows that the explanation given for the albite and muscovite will answer for the microcline and muscovite, the only difference being in the alkali exchanged for the lithium. Generally, however, the mica is absent and then we must write, as in the case of the albite, taking into account the change of alkali,

$$\underset{\text{Spodumene.}}{Li_2Al_2Si_4O_{12}} + 2SiO_2 = \underset{\text{Microcline.}}{K_2Al_2Si_6O_{16}} \qquad (5)$$

There is no reason to think that the microcline was not formed directly from the spodumene; no trace of any potash series to correspond to the β spodumene and cymatolite was observed.

But little additional explanation is needed beyond what has been given, in the case of the coarse complex pseudomorphs, consisting of mica and the two feldspars. The method of their formation is involved in what has been given, the only essential difference being that the conditions were such as to lead to the segregation and simultaneous crystallization of the resulting minerals in large masses instead of as intimate mixtures. In connection with these it is interesting to call attention again to the fact that the masses of microcline in a single crystal, though often isolated and apparently quite independent, are yet in most cases in parallel position. This is a significant fact in its bearing upon the conditions of formation.

These agglomeration pseudomorphs seem to be more abundant at the Massachusetts localities, as described by Mr. Julien,

than with us. Moreover, they differ from those of Branchville in that they contain much more mica and also quartz, which latter mineral with us is practically absent. Mr. Julien, besides his general explanation of the relation of the soda feldspar and muscovite to the original spodumene (which as stated above we have adopted), calls attention to the fact that by an exchange of alkali and the loss of two molecules of silica, spodumene would yield muscovite—that is

$$\underset{\text{Spodumene.}}{Li_2Al_2Si_4O_{12}} = \underset{\text{Muscovite.}}{(K,H)_2Al_2Si_2O_8} + 2SiO_2 \qquad (6)$$

He remarks upon the free quartz present in the pseudomorphs as evidence that this process actually went on.

It is interesting to note in this connection the following statement made by Mr. Julien, he says: "Many pseudomorphs were found in the Chesterfield vein which consist in large part or entirely of a greenish-yellow muscovite with peculiar greasy luster. In fact all stages of intermixture of cymatolite were observed, from the almost pure pseudomorphs of the latter mineral in which muscovite occurred only in minute or even microscopic scales lying mostly parallel to the axis of the crystal—to others in which the mica was so abundant as to have imparted a yellow or greenish color to the mixture, and at last to micaceous pseudomorphs perfectly free from cymatolite retaining the form and superficial striation of the spodumene even to its terminations." He also speaks of the occurrence of large quantities of quartz in the pseudomorphs.

In the specimens we have studied the case is reversed, quartz is nearly entirely absent, mica occurs in separate form only sparingly, and in the formation of the two feldspars there has often been an assumption of silica from some outside source.

Thus far we have said nothing in regard to one important pseudomorphous mineral—the killinite. It seems impracticable to give this a certain place in such a scheme as that given above, for the good reason that its true composition is somewhat in doubt. It is certainly a more or less impure material, having the same want of homogeneity and definite composition that is so often observed among the minerals of the pinite group. The microscopic structure, and, too, the results of the analysis, seem to justify us in the suggestion that it may be essentially a hydrous potash mica, not very unlike that in the cymatolite. In this case its presence is not strange, for the distinction between it and the other would be more in its state of aggregation than in composition. The chemical process which led to the formation of the killinite is in any case clear, for the change consisted essentially in the introduction of potassium and hydrogen in place of lithium, with the loss of silica. It may consequently be expressed by equation (6),

given above, and the silica thus set free may have played a part (see equation 4) in the formation of albite. It is interesting to note that the killinite was probably always formed immediately from the original spodumene, since it so commonly shows its cleavages.

General Summary.—The remarks in the preceding paragraphs may be summed up as follows:—The spodumene was subjected to the action of solutions containing respectively soda and potash. The first action of the soda solution, by the partial exchange of alkali, resulted in the formation, from the spodumene, of an apparently homogeneous but really complex substance, consisting of equal parts molecularly of albite and a new lithia silicate (eucryptite.) A further action of the soda solution (sodium silicate), by the complete change of alkali and the accompanying assumption of silica, led in some cases to the formation of albite. On the other hand, the action of the potash more frequently changed the lithia silicate, above named, into normal muscovite, so that another apparently homogeneous but really complex substance resulted, cymatolite, consisting of muscovite and albite in equal molecular proportions; again, the segregation of these two minerals produced, in place of normal cymatolite, a mixture of separate masses of albite and mica. Still further the action of the potash, by an exchange of alkali and simultaneous assumption of silica, led to the formation of potash-feldspar or microcline. In some cases the result was a coarse mixture of the mica and the two feldspars. Finally, the action of the potash solution, and the simultaneous loss of silica, led to the formation from the original spodumene of a mineral very closely related to mica, namely, killinite.

Two questions arise here, to neither of which we can give a very satisfactory answer. The first is as to the source of the soda and potash involved in the changes that have been described—to this nothing more can be said than that they were probably furnished by the previous decomposition of feldspars, though under just what conditions we are unable to say.

The other question is as to the final disposition of the lithia removed from the spodumene—this seems to have disappeared entirely, unless the fact that some of the biotite in the vein now carries lithia may account for some of it. In this connection it should be stated that the manganese triphylite—lithiophilite—is certainly an original mineral of the vein, and occurs rather abundantly with the massive spodumene. Its decomposition has also led to an increase of this supply of lithia. Furthermore, it is more than possible that the formation of the remarkable series of phosphates of manganese, described by us from this locality, was connected with the extensive changes in the spodumene. The fact that two of the phosphates are almost

unique among that group of minerals in containing alkalies, (see analyses of dickinsonite and fillowite in our earlier papers) would almost prove this. The lithiophilite may be then the original phosphate of manganese from which the others have been derived. We shall return to this last subject at some future time.

A few additional remarks remain to be made. The cymatolite has been subjected to further change beyond that already described. The result is to lead to the formation of a soft soapy white mineral, filled with scales of mica, and obviously an impure kaolin. This is not at all a surprising result; for it is known that kaolin is formed from the soda-feldspar as well as the potash-feldspar, and the finely divided state in which the albite exists in the cymatolite would make it very liable to undergo the well understood change leading to kaolin.

Associated with the soft, partially kaolinized cymatolite, is an interesting pink clay-like mineral, closely related to *montmorillonite*. It also occurs coating the cleavage surfaces of the partially altered spodumene. It is most abundant, however, in independent deposits of considerable extent in the vein not far from the point where the spodumene occurs. It forms soft masses, easily dug out with a spade, and enough of it was found in one spot to fill an ordinary cart. It also penetrates the vein material, filling cavities in the unaltered albite and quartz. It is quite impure, often blackened in spots with manganese oxide, and contains crystals of apatite.

When first exposed it was moist and soft, easily crushed between the fingers, and in the purest parts entirely free from gritty material when placed in the mouth. Upon being exposed to the air for some weeks it lost much of its moisture and hardened considerably.

The color is a delicate rose-pink, growing somewhat lighter on being exposed to the air. It is easily fusible, B. B.

An analysis of the air-dried material was made by Mr. Horace L. Wells, with the following results:—

	I.	II.	Mean.	Ratio.	
SiO_2	51·21	51·19	51·20		·853
Al_2O_3	22·07	22·20	22·14		·118
FeO	*tr.*	--	*tr.*		
MnO	0·16	0·20	0·18	·002	
MgO	3·76	3·68	3·72	·091	
CaO	3·55	3·51	3·53	·030	·130
Li_2O	*tr.*	--	*tr.*		
Na_2O	0·18		0·18	·003	
K_2O	0·38		0·38	·004	
H_2O	17·11	17·04	17·08		·955
P_2O_5	1·40	1·43	1·42		
			99·83		

The phosphoric acid shows that a little apatite was present, and the corresponding amount of lime (1·86) should consequently be deducted. The analysis agrees reasonably well with the analyses of montmorillonite from Montmorillon, France. It is also closely related to a similar clay described by Helmhacker, from Macskamezö, Transylvania.*

It has been stated that this mineral was, as first found, very moist and coherent. It seemed a matter of some interest to determine the way in which it lost its water, and consequently two grams of air-dried mineral were taken and placed in the desiccator over sulphuric acid. Repeated weighings showed that it continued to lose weight gradually for a period of six or seven weeks, the loss being then 9·80 p. c. The total loss after ignition was about 17 p. c.

The exact relation of this montmorillonite to the spodumene pseudomorphs cannot be given. The fact that it occurs so intimately with the spodumene, and too with the cymatolite, seems to imply that it owes its origin to the former. It belongs, however, to a later part of the process, for it is almost entirely free from alkalies. The suggestion that it may have been made from feldspar and thus have afforded the alkalies involved in the alteration of the spodumene would seem at first sight plausible. But in the first place the feldspar of the vein with which it occurs is entirely fresh and unaltered, and then, as far as our observations have yet gone, the quantity is much too small. It would rather seem to be a local result of the further alteration of the cymatolite. We do not feel able at present, however, to speak with decision about it.

In concluding our paper, we would express our acknowledgments to Mr. Penfield, and to Messrs. Wells and Dewey, to whom we are indebted for the analyses here published.

DESCRIPTION OF PLATE.

In the figures the letters employed have the following signification:—a = albite, though here it is to be remembered that (as remarked earlier) most of the albite contains scales of muscovite, and hence shades into cymatolite; c = cymatolite; g = muscovite; k = killinite; m = microcline; s = spodumene; β = β spodumene.

1*a*, 1*b*, 1*c*: Three sections across a single crystal, 15 inches wide and 4½ long, at intervals of about 5 inches. 1*a*, from near the terminated extremity, consists principally of β spodumene (β), with cymatolite (c) along the edges, and a little glassy spodumene (s) on the lower side. 1*b* shows only β spodumene and cymatolite, the latter occupying a larger portion than in 1*a*. 1*c*, from the lower extremity of the crystal shows cymatolite only.

2. Section across a crystal, 4½ inches wide, now entirely altered to cymatolite. The intricate wavy structure of this mineral is shown, as also the tendency of the fibers to be at right angles to the edges.

3. Partial section taken longitudinally; the central portion consists of finely granular albite (a), with lines of coarsely granular, and cleavable, microcline (m); the exterior is cymatolite (c).

* Tschermak. Min. u. Petro. Mitth. 1879, p. 251.

4. Fragment of a crystal showing the granular albite (*a*) inclosing microcline (*m*).

5. Section across a large crystal; the exterior fractured and irregular. It consists mostly of clear pink spodumene (*s*) with bands of β spodumene (β) passing through it, following the directions of the cleavage; also some cymatolite (*c*) on the exterior.

6. Consists of granular albite (*a*), and cymatolite (*c*), also some plates of mica (*g*).

7. Section across a large crystal (natural size), the interior consisting of fibrous albite (*a*) and the exterior cymatolite (*c*).

8. Section showing some of the original spodumene (*s*) in detached points, with cymatolite (*c*) radiating from them, also some β spodumene, granular albite (*a*), and a few plates of mica (*g*).

9. A fragment consisting of killinite (*k*) with narrow bands of cymatolite (*c*) following approximately the original cleavage directions of the spodumene.

10. Section across a large crystal ($7\frac{1}{2}$ inches wide), consisting of albite (*a*) and granular microcline (*m*).

11, 13. Fragments showing granular albite (*a*) and imbedded in it broad cleavage plates of microcline; in each crystal these plates are all in parallel direction.

12. Fragment of a crystal, showing β spodumene (β) inclosed in albite (*a*), the exterior portion consisting of killinite.

14. Portion of a crystal with the spodumene (*s*) cymatolite (*c*) radiating from it, and granular albite (*a*); one band through the spodumene is still β spodumene.

Art. XXX.—*Floating Magnets;* by R. B. Warder and W. P. Shipley.

In repeating Professor Mayer's beautiful experiments with floating magnets,* we have modified the field of magnetic force by sending an electric current through a coil surrounding the vessel of water to repel the floating magnets to the center, either with or without the fixed central magnet. With these modifications, we still have radial lines of force (counting the horizontal component only), the intensity of which varies with the distance from the center of the bowl, but according to two very different functions of this distance. Assuming the solenoidal distribution of magnetism as a sufficient approximation for our present purpose, it may be readily shown that

$$F_1 = k_1 \left(\frac{r}{(r^2+A^2)^{\frac{3}{2}}} - \frac{r}{(r^2+B^2)^{\frac{3}{2}}} + \frac{r}{(r^2+C^2)^{\frac{3}{2}}} - \frac{r}{(r^2+D^2)^{\frac{3}{2}}} \right) \quad (1)$$

in which F_1 = the attraction of each floating magnet towards the center;

k_1 = the force acting between a pole of the central magnet and a pole of a floating magnet, when they are at unit distance;

r = the horizontal distance of the floating magnet from the center of the field, and

A, B, C and D are vertical distances which remain constant in each experiment.

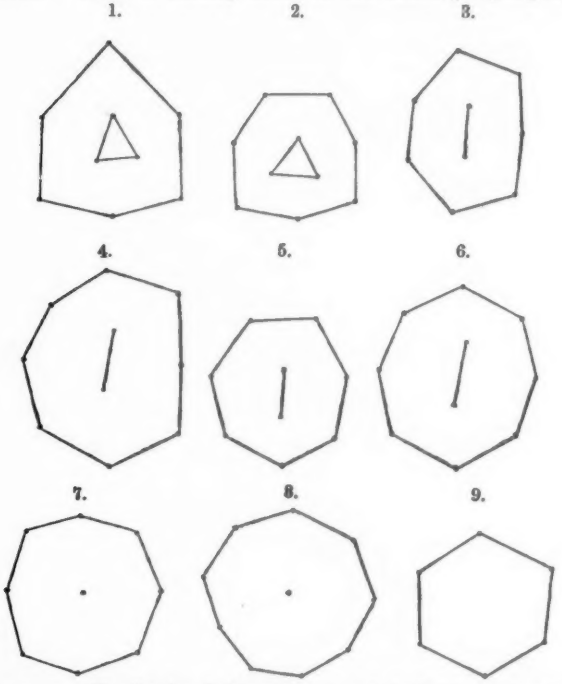
* This Journal, xv, 276, 477, and xvi, 247; 1878.

Under the new method of experiment, on the other hand, if the magnets may be regarded as indefinitely short, Professor I. Sharpless has shown us that

$$F_2 = k_2 \frac{r}{R^2 - r^2} \qquad (2)$$

in which F_2 is the repulsion towards the center,
k_2 is a constant depending upon the current strength and the number of turns in the coil, and
R = radius of the coil.

As may readily be supposed, a variety of configuration with a given number of magnets results from the use of forces which may be varied at will by combining these two unlike functions. This is clearly seen in the accompanying figures,



which were all obtained by taking prints from nature in the usual way. The configurations 1 to 4 were obtained by the original method, with the central attracting magnet; Nos. 5 to 8 by the electric current. These figures represent two parallel series, having 9 and 10 floating magnets respectively. The configuration No. 9 was obtained by the combined repulsion of the central magnet and the current.

An inspection of the first eight figures will show a marked qualitative contrast; for when the force varies according to the law expressed by equation (1) there is a decided tendency toward concentration of magnets near the center of the field, while under law (2) the tendency is toward a greater concentration in the periphery of the figure; under law (1), an angle of the polygon is sometimes very obtuse, under law (2) much greater apparent regularity is seen. In fig. 9, the magnet being reversed, the centralizing tendency becomes negative, and we obtain the figure discussed by Mayer and by Pierce in Nature, vol. xviii, pages 258, 381. In our experiments, the figures 1 and 2, 7 and 8, seemed to be more stable than 3 to 6; Nos. 1 and 2 were not stable without the central attracting magnet; and No. 7 could not be obtained without the repulsion of the electric circuit, unless the magnet was placed at some distance above the water. In this case, an electro-magnet was used, in order to obtain sufficient intensity. Under law (1) the mean distance of neighboring magnets is least in the central part of the figure, under law (2) at the periphery. It will also be seen that the alternation of acuter and obtuser angles in the periphery of figures 1 and 7 is just what is required to equalize, as far as possible, the actual distance of neighboring magnets.

To compare these facts with deductions from the formulas given above, let us consider the purely ideal case of single magnetic poles in one plane with an infinite electric current of infinite radius. The equations (1) and (2) given above may then be reduced by making A equal to zero, and B, C, D and R each equal to infinity, or

$$F_1 = \frac{k_1}{r^2} \qquad (1\ a)$$

$$F_2 = r \times \text{constant} \qquad (2\ a)$$

If we suppose the attracting magnetic pole to be above the plane of floating magnets, equation (1) would become

$$F_1 = k_1 \frac{r}{(r^2 + A^2)^{\frac{3}{2}}}$$

and when the ratio $\frac{A}{r}$ becomes very great, we have (as a close approximation)

$$F_1 = r \times \text{constant} \ (1\ b),\text{--as in eq. } (2\ a)$$

In both forms of experiment, the force very near the center increases directly as the distance; but it soon reaches a maximum under law (1), and then rapidly diminishes, so that three, or at least two, of the floating magnets are held near each other in the central part of the figure. As al-

ready stated, it is only when the zone of maximum force is widened, by raising the central magnet, that fig. 7 is stable without the repulsion of the electric current. In the new form of the experiment, on the other hand, while the force near the center of the field increases directly as the distance, towards the margin it increases still more rapidly, and in this case but one or at most but two of the magnets take their place near the center, as we should expect.

In our ignorance of the mechanical structure of a molecule, or the law of the variation of the force that controls the motions of its several parts, we offer no opinion as to which mode of experiment (both being confined to plane figures) affords the better illustration of the still unknown forms of atomic and molecular configuration. Equation (2), however, is far simpler than equation (1).

Both modes of experimenting are readily carried out, if the necessary precautions are taken; but the attempt fails when the needles are imperfectly magnetized. Our water was drawn from service pipes under considerable pressure, and we were obliged to renew it every ten or fifteen minutes; otherwise the magnets failed to move freely. Whether this would be the case with water freed from an excess of air, we have not determined. In our modification, we used one or two Bunsen cells, with five turns of No. 16 copper wire in a coil of 15 c. m. diameter. A single one-fluid cell is sufficient.

The work already accomplished is only qualitative; but we propose to continue the investigation (both by experiment and by analysis) with regard to the stability of certain figures, under the various modifications of the experiment.

Haverford College, Pa., June, 1880.

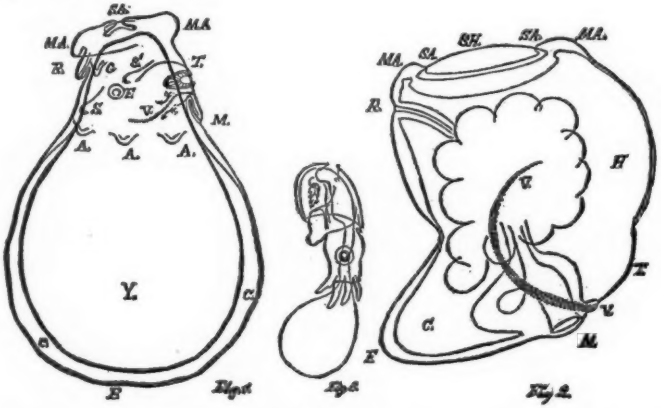
Art. XXXI.—*Notes from the Chesapeake Zoological Laboratory of the Johns Hopkins University.*

No. I.—*The Homology of the Cephalopod Siphon and Arms;* by W. K. Brooks.

While studying the development of the squid (*Loligo Pealii*), I fortunately procured embryos at stages which fill gaps in the account which has been given by Grenacher, and which seem to place the homology between the cephalopoda and the ordinary mollusca in a very clear light, and I give a diagram of an early stage of development of the squid, and another of a gasteropod, in a corresponding stage. Without discussing the literature of the subject I will pass at once to the description of the figures.

Figure 1 is a squid embryo with its head and yolk sac, Y, below, and the so-called posterior end above; the so-called ventral surface, which in the adult carries the siphon, at the left, and the so-called dorsal surface at the right.

Figure 2 is the embryo of a fresh-water pulmonate in a similar position: with the foot, F, below; the shell area, SA, above; the mouth, M, tentacles, T, and head on the right side, and the rectum, R, on the left. The figure therefore shows the right side of the pulmonate.



SH is the bilaterally symmetrical shell, resting like a cap upon the dorsal surface of the body, and surrounded by a reflected ridge of integument, SA, the margin of the shell area.

In the squid, figure 1, there is also an external shell which is surrounded by a reflected ridge of integument, SA, as in the pulmonate.

Running around the shell and shell area, in both, is a second ridge of integument, the margin of the mantle, MA, which, in the cephalopod, already projects a little, forming the outer wall of the rudimentary mantle chamber.

On the median line of the posterior, or *ventral*, surface of the body, just below the mantle ridge, in both, is the rectum, R, with its opening the anus.

In the cephalopod the anus is raised from the surface of the body upon an anal papilla, but in other respects it is alike in the two forms.

On each side of the rectum of the cephalopod is a tentacular gill, G, underneath the projecting edge of the mantle. There are no corresponding structures in the pulmonate.

On the anterior surface of the body, the surface which is usually called dorsal in the cephalopod, and which is on the

right in both figures, we have, first the thickened mantle ridge, MA, which forms the angle between the dorsal and the anterior surface; next we have the long pulsatile "neck" region of the pulmonate, H. In the cephalopod embryo this region is short, not pulsatile, and forms the back.

Below the "neck" of the pulmonate a tentacle, T, is developed on each side of the body, and the eyes subsequently make their appearance upon these tentacles.

On each side of the corresponding region of the body of the cephalopod embryo there is a projecting eye-stalk, T, upon the rounded tip of which the eye is formed by an involution of the integument.

Crossing the middle line of the body of the pulmonate just below the tentacles, is the rudimentary velum, V, which runs out onto the sides and then bends up towards the dorsal surface in such a way as to almost surround the tentacles. This line is marked in the pulmonate by a row of granular ciliated cells.

When the corresponding surface of the body of the cephalopod is examined, a well defined line or groove, V, figure 1, will be found to run from the median line out into the sides of the body, bending up posteriorly in such a way as to nearly surround the eye-stalk. The motion of particles floating in the water shows the presence of ciliary currents, as indicated by the arrows, and there does not seem to be any reason for doubting that this is a true rudimentary velum. In both forms the mouth, M, is situated just below the point where this line crosses the median line of the body.

We have then the following structures which are so similar in position, relations, mode of development, and function, as to leave no doubt of their homology; the mouth; the velum; the sensory tentacles; the mantle; the shell area; the shell; the rectum and the anus.

These features furnish enough points of orientation to assure us that the cephalopod must be placed as it is in our figure 1, in order to be in a position homologous with that of the gasteropod embryo, figure 2. The views which have been advocated by Huxley are therefore essentially correct.

In order to show the relation between figure 1 and an adult cephalopod, I give, in figure 3, an outline sketch, much less magnified, of an older embryo which has acquired most of the adult characteristics. As the position of this figure is like that of the other two the dorsal surface is that which is above, the ventral is below, the anterior surface on the right, the posterior on the left, and the figure shows the left side of the animal.

We are now in a position to discuss the disputed points in cephalopod structures; the homology of the siphon, and the arms; and the equivalent of the gasteropod foot.

The latter, figure 2, F, is a median unpaired structure on the ventral surface of the body between the mouth and the anus. In the pulmonate and in many other gasteropod embryos a large sinus space, C, separates the integument of the foot from the endoderm and its derivatives; the integument is rhythmically pulsatile, and the sinus space has the function of a circulatory organ.

The only unpaired structure on the median line of the ventral surface of the body of the cephalopod embryo is the large food yolk, figure 1, Y, and in this, if any where, we must find the homologue of the gasteropod foot.

In the cephalopod a sinus space, C, separates the food yolk from the layer of integument, F, which surrounds it, and this wall of integument is rhythmically contractile, like the foot of the pulmonate embryo, and I think we must conclude that the cephalopod foot, as a locomotor organ, has been suppressed by the great development of a food yolk at the point where it should be found.

The arms of the squid make their appearance as little elevations, A, A, A, arranged in pairs around the neck or constriction which separates the food yolk from the body proper.

As they are, at first, ventral to the mouth, and as a true velum is present, we cannot accept Grenachers' view that they represent this structure. As they are paired structures we cannot agree with Huxley in regarding them as the representative of the foot, although they are, perhaps, to be regarded as paired outgrowths from the foot-region.

The siphon originates as two pairs of folds, S and S′, of the integument of the lateral walls of the body, and if we follow Huxley in regarding these four folds as homologous with the epipodial folds of a gasteropod, we must regard the arms as structures which have been independently acquired.

If on the other hand we regard the arms as modified epipodial folds we must consider the four siphon folds to be independently acquired structures, and in the absence of any test nothing seems to be gained by the uncertain homology of either the arms or the siphon with any part of the body of a typical gasteropod.

Beaufort, N. C., July 5th, 1880.

No. II.—*Notes on the Early Stages of some Polychætous Annelides;* by E. B. Wilson.

In view of the morphological interest of the marine annelides as the most highly specialized forms among the "Vermes," and the scarcity of detailed accounts of their early stages of development, the following preliminary abstract of studies

on the eggs of *Arenicola* and *Clymenella* seems of some interest. The eggs are small and very numerous, and are embedded in transparent gelatinous masses issuing from the mouths of the tubes or burrows inhabited by the worms. The egg-masses of *Arenicola* are of great size, being sometimes five or six feet in length and from two to four inches in diameter; such a mass must contain several hundred thousand eggs. Those of *Clymenella* are usually about the size and shape of a pigeon's egg; the eggs are much fewer and considerably larger than those of *Arenicola*.

The whole course of development is essentially alike in the two forms. No polar globules of constant relation to the yolk were observed. The first cleavage divides the egg into two unequal spherules. The second, passing at right angles to the first, divides the smaller spherule into two equal parts, and the larger into two unequal parts. The third cleavage separates from these four blastomeres four much smaller ones at one pole of the egg. The latter (micromeres) soon become so displaced as to alternate with the former (macromeres). The micromeres now divide more rapidly than the macromeres which they come ultimately to include by growing down over them. The ectoderm is formed by the derivatives of the micromeres, and in part, I believe, of the macromeres. The remaining portions of the macromeres form the entoderm. Two large spherules, which originally formed a part of the largest of the four primary blastomeres, are visible up to a late stage at the posterior extremity of the embryo. They are at first at the surface but ultimately are grown over by the ectoderm and disappear. It is possible that they are concerned in the formation of the mesoderm and are to be regarded as primary mesoblasts. The mouth arises on the ventral side nearly opposite that pole of the egg where the first four micromeres were formed. The anus arises at the posterior end of the embryo. The egg-membrane is directly converted into the cuticle of the larva. The egg exhibits, during segmentation, alternate periods of activity and quiescence.

The embryo acquires two dorsal eye-specks, præ-oral and præ-anal belts of cilia and a broad ventral band, and becomes a "Telotrochous" larva which passes directly into the adult. The setæ develop from before backwards, and those of the dorsal ramus appear before those of the ventral.

The segmentation is closely similar to that of some Oligochæta (*Euaxes*, *Tubifex*) and resembles also that of the leeches. The gastrula stage is not attained by a typical invagination but by a down-growth of the ectoderm over the entoderm.

Beaufort, N. C., July, 1880.

No. III.—*The Rhythmical Character of the Process of Segmentation;* by W. K. Brooks.

A number of observers have called attention to the fact that in certain animals the segmenting eggs pass through alternating stages in which the segmentation products are first conspicuous and well defined, and then flattened and fused together.

In a paper on the development of the fresh water pulmonates I have attempted to show that the alternation is due to the fact that periods of segmenting activity alternate with periods of rest, and that the tendency which the elasticity of the egg exerts to render its form spherical when no other force is acting upon it causes the partial obliteration of the outlines of the spherules during each resting stage.

The essential factor is therefore the alternation of rest with activity, and the change of shape during the resting periods is a secondary phenomenon, brought about incidentally by the physical properties of the yolk.

In most eggs the yolk is not sufficiently elastic to allow any great change of form, but careful time-records show that the process of segmentation is rhythmical, and that short periods of active change alternate with longer periods during which there is no external change.

During the past year various members of the Biological Department of the University have observed this alternation in various Vertebrate and Invertebrate eggs. Dr. Clarke has noticed it in an amphibian, *Amblystoma*, where the segmentation is total. I have observed it in the egg of an unknown fish, where segmentation is restricted to a blastoderm. Mr. Wilson has observed it in three annelides, where segmentation is total and irregular; *Arenicola*, *Clymenella* and *Lumbricus*. It is very well marked in an arthropod, *Leucifer*, whose eggs undergo total regular segmentation.

Its occurrence in so many widely separated groups, with such different methods of segmentation renders it probable that it will be found in nearly all eggs upon sufficiently careful examination.

ART. XXXII.—*Paleontological and Embryological Development;* Address by ALEXANDER AGASSIZ, Vice-president of Section B, at the recent Boston meeting of the American Association for the Advancement of Science.

SINCE the publication of the "Poissons Fossiles" by Agassiz, and of the "Embryologie des Salmonidées" by Vogt, the similarity, traced by the former between certain stages in the growth of young fishes and the fossil representatives of extinct members of the group, has also been observed in nearly every class of the animal kingdom, and the fact has become a most convenient axiom in the study of paleontological and embryological development. This parallelism, which has been on the one side a strong argument in favor of design in the plan of creation, is now, with slight emendations, doing the duty on the other as a newly discovered article of faith in the new biology.

But while in a general way we accept the truth of the proposition that there is a remarkable parallelism between the embryonic development of a group and its paleontological history, yet no one has attempted to demonstrate this, or rather to show how far the parallelism extends. We have, up to the present time, been satisfied with tracing the general coincidence, or with striking individual cases.

The resemblance between the pupa stage of some Insects and of adult Crustacea, the earlier existence of the latter, and the subsequent appearance of the former in paleontological history, furnished one of the first and most natural illustrations of this parallelism; while theoretically the necessary development of the higher tracheate insects from their early branchiate aquatic ancestors seemed to form an additional link in the chain, and point to the Worms, the representatives of the larval condition of Insects, as a still earlier embryonic stage of the Articulates.

Indeed, there is not a single group of the animal kingdom in which embryology has not played a most important part in demonstrating affinities little suspected before. The development of our frogs, our salamanders, has given us the key to much that was unexplained in the history of Reptiles and Batrachians. The little that has been done in the embryology of Birds has revolutionized our ideas of a class which at the beginning of the century seemed to be the most naturally circumscribed of all. Embryology and paleontology combined have led to the recognition of a natural classification uniting Birds and Reptiles on the one side and Batrachians and Fishes

on the other. It is to embryology that we owe the explanation of the affinities of the old Fishes in which Agassiz first recognized the similarity to the embryo of Fishes now living, and by its aid we may hope to understand the relationship of the oldest representatives of the class. It has given us the only explanation of the early appearance of the Cartilaginous Fishes, and of the probable formation of the earliest vertebrate limb from the lateral embryonic fold, still to be traced in the young of the Osseous Fishes of to-day.

Embryology has helped us to understand the changes aquatic animals must gradually undergo in order to become capable of living upon dry land. It has given us pictures of swimming-bladders existing as rudimentary lungs in Fishes with a branchial system; in Batrachians it has shown us the persistence of a branchial system side by side with a veritable lung. We find among the earliest terrestrial Vertebrates types having manifest affinities with the Fishes on one side and Batrachians on the other, and we call these types Reptiles; but we should nevertheless do so with a reservation, looking to embryology for the true meaning of these half-fledged Reptiles, which lived at the period of transition between an aquatic and a terrestrial life, and must therefore always retain an unusual importance in the study of the development of animal life.

When we come to the embryology of the marine Invertebrates, the history of the development of the barnacles is too familiar to be dwelt upon, and I need only allude to the well-known transformations of the Echinoderms, of the Acalephs, Polyps, in fact of every single class of Invertebrates, and perhaps in none more than in the Brachiopods, to show how far-reaching has been the influence of embryology in guiding us to a correct reading of the relations between the fossils of successive formations. There is scarcely an embryological monograph now published dealing with any of the later stages of growth which does not speak of their resemblance to some type of the group long ago extinct. It has therefore been most natural to combine with the attempts constantly made to establish the genetic sequence between the genera of successive formations an effort to establish also a correspondence between their paleontological sequence and that of the embryonic stages of development of the same, thus extending the mere similarity first observed between certain stages to a far broader generalization.

It would carry me too far to sketch out, except in a most general way, even for a single class, the agreement known to exist in certain groups between their embryonic development and their paleontological history. It is hinted at in the succession of animal life of any period we may take up, and per

haps cannot be better expressed than by comparing the fauna of any period as a whole with that of following epochs;—a zoölogical system of the Jura, for instance, compared with one made up for the Cretaceous; next, one for the Tertiary, compared with the fauna of the present day. In no case could we find any class of the animal kingdom bearing the same definitions or characterized in the same manner. But apply to this comparison the data obtained from the embryological development of our present fauna, and what a flood of light is thrown upon the meaning of the succession of these apparently disconnected animal kingdoms, belonging to different geological periods, especially in connection with the study of the few ancient types which have survived to the present day from the earliest times in the history of our earth!

Although there is hardly a class of the animal kingdom in which some most interesting parallelism could not be drawn, and while the material for an examination of this parallelism is partially available for the Fishes, Mollusks, Crustacea, Corals, and Crinoids, yet for the illustration and critical examination of this parallelism, I have been led to choose to-day a very limited group, that of Sea-urchins, both on account of the nature of the material and of my own familiarity with their development and with the living and extinct species of Echini. The number of living species is not very great—less than three hundred—and the number of fossil species thus far known is not, according to Zittel, more than about two thousand. It is therefore possible for a specialist to know of his own knowledge the greater part of the species of the group. It has been my good fortune to examine all but a few of the species now known to exist, and the collections to which I have had access contain representatives of the majority of the fossil species. Sea-urchins are found in the oldest fossiliferous rocks; they have continued to exist without interruption in all the strata up to the present time. While it is true that our knowledge of the Sea-urchins occurring before the Jurassic period is not very satisfactory, it is yet complete enough for the purposes of the present essay, as it will enable me, starting from the Jurassic period, to call your attention to the paleontological history of the group, and to compare the succession of its members with the embryological development of the types now living in our seas. Ample material for making this comparison is fortunately at hand; it is material of a peculiar kind, not easily obtained, and which thus far has not greatly attracted the attention of zoölogists.

Interesting and important as are the earliest stages of embryonic development in the different classes of the animal kingdom, as bearing upon the history of the first appearance of

any organ and its subsequent modifications, they throw but little light on the subject before us. What we need for our comparisons are the various stages of growth through which the young Sea-urchins of different families pass from the time they have practically become Sea-urchins until they have attained the stage which we now dignify with the name of species. Few embryologists have carried their investigations into the more extended field of the changes the embryo undergoes when it begins to be recognized as belonging to a special class, and when the knowledge of the specialist is absolutely needed to trace the bearing of the changes undergone, and to understand their full meaning. Fortunately the growth of the young Echini has been traced in a sufficient number of families to enable me to draw the parallelism between these various stages of growth and the paleontological stages in a very different manner from what is possible in other groups of the animal kingdom, where we are overwhelmed with the number of species, as in the Insects or Mollusks, or where the paleontological or the embryological terms of comparison are wanting or very imperfect.

Beginning with the paleontological history of the regular Sea-urchins at the time of the Trias, when they constituted an unimportant group as compared with the Crinoids, we find the Echini of that time limited to representatives of two families. One of these, the genus Cidaris, has continued to exist, with slight modifications, up to the present time, and not less than one-tenth of all the known species of fossil Echini belong to this important genus, which in our tropical seas is still a prominent one. It is interesting here to note that in the Cidaridæ the modifications of the test are not striking, and the fossil genera appearing in the successive formations are distinguished by characters which often leave us in doubt as to the genus to which many species should be referred. In the genus Rhabdocidaris, which appears in the lower Jura, and which is mainly characterized by the extraordinary development of the radioles, we find the extreme of the variations of the spines in this family. From that time to the present day, the most striking differences have existed in the shape of the spines, not only of closely allied genera, but even in specimens of the same species; differences which in some of the species of to-day are as great as in older geological periods. The oldest Cidaridæ are remarkable for their narrow poriferous zones. It is only in the Jura that they widen somewhat; subsequently the pores become conjugated, and only later, during the Cretaceous period, do we find the first traces of any ornamentation of the test (Temnocidaris) so marked at the present day in the genus Goniocidaris. As far, then, as the Cidaridæ are concerned, the

modifications which take place from their earliest appearance are restricted to slight changes in the poriferous zone and in the ornamentation of the test, accompanied with great variability in the shape of the primary radioles. We must except from this statement the genera Diplocidaris and Tetracidaris, to which I shall refer again. The representatives of the other Triassic family become extinct in the lower Tertiaries. The oldest genus, Hemicidaris, undoubtedly represents the earliest deviations from the true Cidaris type; modifications which affect not only the poriferous zone, but the test, the actinal and the abactinal systems, while from the extent of these minor changes we can trace out the gradual development of some of the characteristics in families of the regular Echini now living. The genus Hemicidaris may be considered as a Cidaris in which the poriferous zone is narrow and undulating, in which the granules of the ambulacral system have become minute tubercles in the upper portion of the zone and small primary tubercles in its actinal region, in which many of the interambulacral granules become small secondaries, in which the plates of the actinal system have become reduced in number, and the apical system has become a narrow ring, and finally in which the primary radioles no longer assume the fantastic shapes so common among the Cidaridæ.

We can trace in this genus the origin of the modifications of the poriferous zone, leading us, on the one side, through genera with merely undulating lines of pores to more or less distinct confluent arcs of pores, formed round the primary ambulacral tubercles, and, on the other, to the formation of open arcs of three or more pairs of pores. The first type culminates at the present day with the Arbaciadæ, the other with the Diadematidæ, Triplechinidæ, and Echinometradæ. This specialization very early takes place, for already in the lower Jura Stomechinus has assumed the principal characteristics of the Triplechinidæ of to-day.

Although in Hemicidaris the number of the coronal plates has increased as compared with the Cidaridæ, and while we find that in many genera, even of those of the present day, the number of the coronal plates is still comparatively small, yet, as a general rule, the more recent formations contain genera in which the increase in number of the interambulacral plates is accompanied by a corresponding decrease in the number of plates of the interambulacral area so characteristic thus far of the Cidaridæ and Hemicidaridæ, a change also affecting the size of the primary ambulacral tubercles. This increase in the number of the coronal plates is likewise accompanied by the development of irregular secondary and miliary tubercles, and the disappearance in this group of the granular tuberculation,

so important a character in the Cidaridæ. With the increase in the number of the interambulacral coronal plates, the Pseudodiadematidæ still retain prominent primary tubercles, recalling the earlier Hemicideridæ and Cidaridæ, and, as in the Cidaridæ proper, the test is frequently ornamented by deep pits or by ridges formed by the junction of adjoining tubercles. The genital ring becomes narrower, and the tendency to the specialization of one of its plates, the madreporite, more and more marked.

With the appearance of Stomechinus, the Echinidæ proper already assume in the Jura the open arcs of pores, the large number of coronal interambulacral plates, the specialization of the secondary tubercles, and the large number of primary tubercles in each plate. With the appearance of Sphærechinus in the early Tertiary come in all the elements for the greater multiplication of the pairs of pores in the arcs of the poriferous zones, while the gigantic primary spines of some of the genera (Heterocentrotus), and the small number of primary tubercles are structural features which had completely disappeared in the group preceding the Echinometradæ, to which they appear most closely allied.

Going back again to the Hemicidaridæ, it requires but slight changes to pass from them to Acrosalenia and to the Saleniæ proper; the latter have continued to the present day, and have, like the Cidaridæ, retained almost unchanged the characters of the genera which preceded them, combined, however, with a few Cidaridian and Echinid features which date back to the Triassic period. We can thus trace the modifications which have taken place in the poriferous zone, the apical and actinal systems, the coronal plates, the ambulacral and interambulacral tubercles, as well as in the radioles, and in the most direct manner possible indicate the origin of the peculiar combination of structural features which we find at any geological horizon. On taking in succession the modifications undergone by the different parts of the test, we can trace each one singly, without the endless complication of combinations which any attempt to trace the whole of any special generic combination would imply.

Leaving out of the question for the moment the Palæchinidæ, we find no difficulty in tracing the history of the characters of the genera of the regular Echini which have existed from the time of the Trias and are now living, provided we take up each character independently. Nothing can be more direct than the gradual modification of the simple, barely undulating poriferous zone, made up of numerous ambulacral plates covered by granules, such as we find it among the Cidaridæ of the Trias, first into the slightly undulating poriferous

zone of the Hemicidaridæ, next into the indistinct arcs of pores of the Pseudodiadematidæ, then into the arcs with a limited number of pores of the Triplechinidæ, and finally to the polyporous arcs of the Echinometradæ. What can be more direct than the gradual modification to be traced in the development of the primary ambulacral tubercles, such as are characteristic of the Echinidæ of the present day, from their first appearance at the oral extremity of the ambulacral system of the Hemicidaridæ, and the increase in the number of primary interambulacral tubercles, accompanied by the growth of secondaries and miliaries, which we can trace in Hemicidaris, Acrosalenia, and Stomechinus,—the increase in number of the primary and secondary tubercles being accompanied by a reduction in the size of the radioles and a greater uniformity in their size and shape?

But while these modifications take place, the original structural feature may be retained in an allied group. Thus the Cidaridæ retain unchanged from the earliest time to the present day the few primary tubercles, the secondary granules, the simple poriferous zone, the imbricating actinal system, and the few coronal plates, with the large apical system and many-shaped radioles; while in the Salenidæ the primary interambulacral tubercles, the secondary granules, the radioles, the genital ring, are recognized features of the Cidaridæ, associated, however, with an Echinid actinal and anal system, Hemicidarid primary ambulacral tubercles, and an Echinid poriferous zone. In the same way in the Diadematidæ, the large primary interambulacral tubercles are Cidaridian features, while the structure of the ambulacral tubercles is Hemicidaridian. The existence of two kinds of spines is another Cidaridian feature, while the apical and actinal systems have become modified in the same direction as that of the Echinidæ. The more recent the genus, the greater is the difficulty of tracing in a direct manner the origin of any one structural feature, owing to the difficulty of disassociating structural elements characteristic of genera which may be derived from totally different sources. This is particularly the case with genera having a great geological age. Many of them, especially among the Spatangoids, show affinities with genera following them in time, to be explained at present only on the supposition that, when a structural feature has once made its appearance, it may reappear subsequently, apparently as a new creation, while in reality it is only its peculiar combination with structural features with which it had not before been associated (a new genus), which conceals in that instance the fact of its previous existence. A careful analysis, not only of the genera of the order, but sometimes of other orders which have preceded this combination in time, may often reveal the elements from which have been produced apparently unintelligible modifications.

There is, however, not one of the simple structural features in the few types of the Triassic and Liassic Echini from which we can so easily trace the origin of the structural features of all the subsequent Echinid genera, which is not also itself continued to the present day in some generic type of the present epoch, fully as well characterized as it was at the beginning. In fact, the very existence to-day of these early structural features seems to be as positive a proof of the unbroken systematic affinity between the Echini of our seas and those of the Trias, as the uninterrupted existence of the genus Pygaster or Cidaris from the Trias down to the present epoch, or of the connection of many of the genera of the Chalk with those of our epoch (Salenia, Cyphosoma, Psammechinus, etc.).

Passing to the Clypeastridæ, we find there as among the Desmosticha that the earliest type, Pygaster, has existed from the Trias to the present time; and that, while we can readily reconstruct, on embryological grounds, the modifications the earliest Desmosticha-like Echini should undergo in order to assume the structural features of Pygaster, yet the early periods in which the precursors of the Echinoconidæ and Clypeastridæ are found have thus far not produced the genera in which these modifications actually take place. But, starting from Pygaster, we naturally pass to Holectypus, to Discoidea, to Conoclypus, on the one side, while on the other, from Holectypus to Echinocyamus, Sismondia, Fibularia, and Mortonia, we have the natural sequence of the characters of the existing Echinanthidæ, Laganidæ, and Scutellidæ, the greater number of which are characteristic of the present epoch. If we were to take in turn the changes undergone in the arrangement of the plates of the test, as we pass from Pygaster to Holectypus, to Echinocyamus, and the Echinanthidæ, we should have in the genera which follow each other in the paleontological record an unbroken series showing exactly what these modifications have been. In the same way, the modifications of the abactinal and anal systems, and those of the poriferous zone, can equally well be followed to Echinocyamus, and thence to the Clypeastridæ; while a similar sequence in the modifications of these structural features can be followed from Mortonia to the Scutellidæ of the present period.

Passing finally to the Petalosticha, we find no difficulty in tracing theoretically the modifications which our early Echinoconidæ of the Lias should primarily undergo previous to the appearance of Galeropygus. The similarity of the early Cassiduloid and Echinoneoid types points to the same systematic affinity, and perhaps even to a direct and not very distant relationship with the Palæchinidæ. For if we analyze the Echinothuriæ of the present day, we find in genera like Phormosoma

many structural features, such as the shape of the test, the character of the spines, the structure of the apical system, that of the poriferous zone, indicative of possible modifications in the direction of Pygaster or of Galeropygus, which have as yet not been taken into account.

Adopting for the Petalosticha the same method of tracing the modifications of single structural features in their paleontological succession, we trace the comparatively little modified paleontological history of the Echinoneidæ of the present day from the Pyrina of the lower Jura. This, in its turn, has been preceded by Hyboclypus and Galeropygus, while the Echinolampadæ of the present day date back, with but trifling modifications, to the Echinobrissus of the Lias, itself preceded by Clypeus: and they have been subject only to slight generic changes since that time, Echinobrissus being still extant, while such closely allied genera as Catopygus and Cassidulus of the earlier Cretaceous are still represented at the present day: the modifications taking place in the actinal system, in the ambulacral zones of the Echinoconidæ and of the Echinolampadæ showing the closest possible systematic affinity in these families. Starting again from Hyboclypus, with its elongate apical system, we naturally pass to Collyrites and the strange Dysasteridæ forms which in their turns are closely allied to the Holasteridæ. From Holaster on the one side and from Toxaster on the other, we find an unbroken sequence of structural characters uniting the successive genera of Holasteridæ, such as Cardiaster, Offaster, Stenonia, Ananchytes, and Asterostoma, with Paleopneustes, Homolampas and the Pourtalesiæ of the present day, while from the genera of the Toxasteridæ we naturally pass to the cretaceous Hemiaster; in this genus and subsequent Micraster we find all the elements necessary for the modifications which appear in the Spatanginæ from the time of the Chalk to the present day. These modifications result in genera in which we trace the development of the fascioles, of the actinal, anal, and abactinal plastrons, of the beak, the formation of the petaloid ambulacra, first flush with the test, and little by little changed into marsupial pouches, the growth of the anterior groove and the manifold modifications of the ambulacral system in Spatangus, Agassizia, and Echinocardium, often recalling in some of its features structural characters of families which have preceded this in time.

Apparently in striking contrast with the Echini of the secondary period and those which have succeeded them stand the Paleozoic Echini; but when we have examined the embryology of Echini, we shall be better prepared to understand their structure and the affinities of the Palæchinidæ with the Echini of the present day and their immediate predecessors.

[To be continued.]

Art. XXXIII.—*New Planetary Nebulæ;* by Edward C. Pickering.

Measurements of the light of the planetary nebulæ have been made during the past year with the fifteen-inch telescope of the Harvard College Observatory. In connection with these observations the spectrum of each nebula has also been examined. A spectroscope of the usual form would be open to many objections for this work, especially as it must be frequently removed, and replaced by the photometer. Accordingly a direct-vision prism was placed between the eye-piece and objective of the telescope, thus forming a spectroscope without a slit. When a star was brought into any part of the field it was spread out into a colored line of light, the rays of each wave-length forming an image of the star in a different place. A nebula, on the other hand, being mainly monochromatic, would form a point or small disk of light, while a minute cluster would give a spectrum like that of a star. The difference in these appearances is so marked that the idea suggested itself that this device might serve to detect any minute planetary nebulæ, which could not otherwise be distinguished from stars. Accordingly a systematic search for such bodies was undertaken. A power of about 140 is employed with a field 12′ in diameter. The telescope is clamped in right ascension and moved through 5° in declination. This is repeated so frequently that the successive sweeps shall overlap, the region continually varying by the diurnal motion. Great numbers of stars pass through the field and are spread out into lines. The position of any object presenting a different appearance is at once determined by observing the declination and time, The position of bright stars are also observed to furnish corrections for the limits of the zone. Various precautions must be taken; for instance, if the spectra run north and south, the lines cannot be distinguished from points, when the telescope is moved, owing to the persistence of vision. The prism is therefore always turned so that the direction of the spectra shall be perpendicular to the line of motion. Even then the eye is constantly deceived and an object thought to be a nebula is seen to be a star when the telescope is stopped. The retina appears to be especially sensitive to rays of particular wave-lengths. The strain upon the eye and mind in examining so many objects, several a second, renders this work very fatiguing and I have found it best not to continue it for more than half an hour without an intermission. A count of the number of stars to be seen at a time in fields taken at random shows

that the spectra of over ten thousand stars are often examined in this time.

The first sweep was made on July 13, and revealed in a few minutes a bright point of light wholly unlike the lines formed by the stars. This proved to be a new planetary nebula having the position for 1880 R. A. $18^h\ 25{\cdot}2^m$ and Dec. $-25°\ 13'$. Its disk is so small that it can scarcely be distinguished from a star and would not probably have been detected with an ordinary eye-piece even if brought into the field of view. Measures of its light show that it is about eight magnitudes fainter than λ *Sagittarii* or of about the eleventh magnitude on the scale of Pogson. The next evening another new nebula was found somewhat fainter than this, but with a larger disk. Its position for 1880 is R. A. $18^h\ 4{\cdot}3^m$ and Dec. $-28°\ 12'$. This region was selected since it contains four of the fifty previously known planetary nebulæ. Sweeps on several subsequent evenings in this vicinity and elsewhere revealed nothing new.

On August 28 an object entered the field having a very singular spectrum. Two bright bands were seen near the ends of a faint continuous spectrum. The position of this object for 1880 was found to be R. A. $18^h\ 1^m\ 17^s$, Dec. $-21°\ 16'$. It therefore is identical with the star Oeltzen No. 17681. Its position was observed once by Argelander and twice in the Washington zones. It must therefore have had nearly its present position and brightness over thirty years ago. It appears to be slightly fainter than Oeltzen No. 17648 which precedes it about a minute and is $4'$ north, so that even a small change in its light can be easily detected hereafter. A careful examination of the spectrum shows that the bright portions are longer than they are wide, and accordingly that they are bands and not lines. This view was confirmed by attaching a spectroscope of the usual form to the telescope. The less refrangible band extends from the wave-length 5800 to 5850, the other from 4670 to 4730. A third band was suspected at about 5400. All these measures are only approximate, and should be repeated at some observatory where spectroscopy is made a special study. A large telescope is needed, since at best the spectrum of so faint a star will not be easily measured. It will be noticed that the first of these bands is in the yellow not far from the D line, but of somewhat less wave-length. The other band is in the blue between the F and G lines. This spectrum is unlike that of any other source of light so far as is yet known. It is difficult to know in what class to place this body. From its spectrum of bright bands on a faint continuous back-ground, we might place it with the nebulæ, since most of the planetary nebulæ seem to have a faint, continuous

spectrum not due to the presence of stars in their vicinity. The material of which this object is composed must, however, be different. On the other hand, it resembles a star in other respects, showing no disk and having a much greater intrinsic brightness than other nebulæ.

The fourth new object was discovered on September 2, and consists of a very minute nebula in R. A., $18^h\ 14{\cdot}3^m$ and Dec. $-26°\ 53'$. This is the smallest planetary nebula known and could not be distinguished from a thirteenth magnitude star in an ordinary telescope. The difference between it and a star is, however, very marked in the prism, and had it been a magnitude fainter its peculiar character would probably have been detected.

It is estimated that the spectra of about a hundred thousand stars have so far been examined, although only about one hundredth part of the heavens has as yet been explored. A more rapid survey of the whole heavens is also being made with a comet-seeker of about four-inches aperture, to show the presence or absence of peculiarities in the spectra of the brightest stars.

Cambridge, U. S., Sept. 7, 1880.

ART. XXXIV.—*On the Production and Reproduction of Sound by Light;* by ALEXANDER GRAHAM BELL, Ph.D.

[Read before the American Association for the Advancement of Science, in Boston, August 27, 1880.]

IN bringing before you some discoveries made by Mr. Sumner Tainter and myself, which have resulted in the construction of apparatus for the production and reproduction of sound by means of light, it is necessary to explain the state of knowledge which formed the starting point of our experiments.

I shall first describe that remarkable substance "selenium," and the manipulations devised by previous experimenters; but the final result of our researches has widened the class of substances sensitive to light vibrations, until we can propound the fact of such sensitiveness being a general property of all matter.

We have found this property in gold, silver, platinum, iron, steel, brass, copper, zinc, lead, antimony, german-silver, Jenkin's metal, Babbitt's metal, ivory, celluloid, gutta-percha, hard rubber, soft vulcanized rubber, paper, parchment, wood, mica, and silvered glass; and the only substances from which we have not obtained results, are carbon and thin microscope glass.*

* Later experiments have shown that these are not exceptions.

We find that when a vibratory beam of light falls upon these substances *they emit sounds*, the pitch of which depends upon the frequency of the vibratory change in the light. We find farther, that when we control the form or character of the light, vibrations on selenium (and probably on the other substances), we control the quality of the sound, and obtain all varieties of articulate speech. We can thus, without a conducting wire as in electric telephony, speak from station to station wherever we can project a beam of light. We have not had the opportunity of testing the limit to which this photophonic effect may be extended, but we have spoken to and from points 213 meters apart; and there seems no reason to doubt that the results will be obtained at whatever distance a beam of light can be flashed from one observatory to another. The necessary privacy of our experiments, hitherto, has alone prevented any attempts at determining the extreme distance at which this new method of vocal communication will be available.

I shall now speak of selenium.

Selenium.—In the year 1817, Berzelius and Gottlieb Gahn made an examination of the method of preparing sulphuric acid in use at Gripsholm. During the course of this examination they observed in the acid a sediment of a partly reddish, partly clear brown color, which under the action of the blowpipe gave out a peculiar odor, like that attributed by Klaproth to tellurium.

As tellurium was a substance of extreme rarity, Berzelius attempted its production from this deposit, but he was unable after many experiments to obtain farther indications of its presence. He found plentiful signs of sulphur mixed with mercury, copper, tin, zinc, iron, arsenic and lead, but no trace of tellurium.

It was not in the nature of Berzelius to be disheartened by this result. In science every failure advances the boundary of knowledge as well as every success; and Berzelius felt that if the characteristic odor that had been observed did not proceed from tellurium, it might possibly indicate the presence of some substance then unknown to the chemist. Urged on by this hope he returned with renewed ardor to his work.

He collected a great quantity of the material and submitted the whole mass to various chemical processes. He succeeded in separating successively the sulphur, the mercury, the copper, the tin and the other known substances, whose presence had been indicated by his tests; and after all these had been eliminated, there still remained a residue, which proved upon examination to be what he had been in search of—*a new elementary substance.*

The chemical properties of this new element were found to resemble those of tellurium in such a remarkable degree that Berzelius gave to the substance the name of "selenium," from the Greek word *σελήνη*, the moon, ("tellurium," as is well known, being derived from *tellus*, the earth). Although tellurium and selenium are alike in many respects, they differ in their electrical properties; tellurium being a good conductor of electricity, and selenium, as Berzelius showed, a non-conductor.

Knox* discovered in 1837, that selenium became a conductor when fused; and Hittorff† in 1851, showed that it conducted at ordinary temperatures when in one of its allotropic forms.

When selenium is rapidly cooled from a fused condition it is a non-conductor. In this, its "vitreous" form, it is of a dark brown color, almost black by reflected light, having an exceedingly brilliant surface. In thin films it is transparent, and appears of a beautiful ruby red by transmitted light.

When selenium is cooled from a fused condition with *extreme slowness*, it presents an entirely different appearance, being of a dull lead color, and having throughout a granular or crystalline structure and looking like a metal. In this form it is opaque to light even in very thin films. This variety of selenium has long been known as "granular" or "crystalline" selenium; or as Regnault called it, "metallic" selenium. It was selenium of this kind that Hittorff found to be a conductor of electricity at ordinary temperature.

He also found that its resistance to the passage of an electrical current diminished continuously by heating up to the point of fusion; and that the resistance suddenly increased in passing from the solid to the liquid condition.‡

It was early discovered that exposure to sunlight§ hastens the change of selenium from one allotropic form to another; and this observation is significant in the light of recent discoveries.

Although selenium has been known for the last sixty years, it has not yet been utilized to any extent in the arts, and it is still considered simply as a chemical curiosity. It is usually supplied in the form of cylindrical bars. These bars are sometimes found to be in the metallic condition, but more usually they are in the vitreous or non-conducting form.

It occurred to Willoughby Smith that, on account of the high resistance of crystalline selenium, it might be usefully employed at the shore-end of a submarine cable, in his system

* Trans. Roy. Irish Acad. (1839), xix, 147; also Phil. Mag. III, xvi, 185.
† Pogg. Ann., lxxxiv, 214; also Phil. Mag., IV, iii, 546.
‡ See Draper and Moss in Proc. Roy. Irish Acad., Nov. 1873, II, vol. i, p. 529.
§ Gmelin's Handbook of Chemistry (1849,) ii, 235; see also Hittorff in the Phil. Mag. (1842,) IV, iii, 547.

of testing and signaling during the process of submersion. Upon experiment the selenium was found to have all the resistance required; some of the bars employed measuring as much as 1400 megohms—a resistance equivalent to that which would be offered by a telegraph wire long enough to reach from the earth to the sun! But the resistance was found to be extremely variable. Efforts were made to ascertain the cause of this variability, and it was discovered that *the resistance was less when the selenium was exposed to light than when it was in the dark!*

This observation was first made by Mr. May*—(Mr. Willoughby Smith's assistant, stationed at Valentia)—was soon verified by a careful series of experiments, the results of which were communicated by Mr. Willoughby Smith† to the Society of Telegraph Engineers, on the 17th of February, 1873. Platinum wires were inserted into each end of a bar of crystalline selenium, which was then hermetically sealed in a glass tube through the ends of which the platinum wires projected for the purpose of connection. One of these bars was placed in a box, the lid of which was closed so as to shade the selenium, and the resistance of the substance was measured.

Upon opening the lid of the box the resistance instantaneously diminished. When the light of an ordinary gas burner (which was placed at a distance of several feet from the bar,) was intercepted by shading the selenium with the hand, the resistance again increased; and upon passing the light through rock salt, and through glasses of various colors, the resistance was found to vary according to the amount of light transmitted. In order to be certain that temperature had nothing to do with the effect, the selenium was placed in a vessel of water so that the light had to pass through a considerable depth of water in order to reach the selenium. The effects, however, were the same as before. When a strong light from the ignition of a narrow band of magnesium was held about nine inches above the water, the resistance of the selenium immediately fell more than two-thirds, returning to the normal condition upon the removal of the light.

The announcement of these results naturally created an intense interest among scientific men, and letters of enquiry regarding the details of the experiment soon appeared in the columns of Nature, from Harry Napier Draper‡ and Lieut. M. L. Sale,§ which were answered in the next number by Willoughby Smith.‖

* See lecture by Siemens in Proc. Roy. Inst. of Great Britain, vol. viii, p. 68.

† Jour. of Soc. of Teleg. Engin., ii, p. 31 (1873); Nature, vii, 303; Teleg. Journal, III, (1873), v, 301.

‡ Nature, vii, 340, March 6th, 1873.

§ Ibid.

‖ Nature, vii, 361, March 13th, 1873.

Sale and Draper were soon able to corroborate the statements that had been made by Willoughby Smith.

Sale* presented his researches to the Royal Society on the 8th of May, 1873, and in the following November, Draper† presented his results to the Royal Irish Academy in the shape of a joint paper by himself and Richard J. Moss.

Draper and Moss gave in their paper an admirable summary of the condition of our knowledge regarding selenium at that time. They confirmed Hittorff's observation that the temperature of minimum resistance of granular selenium was somewhere about 210° C., and that at 217° C. (the fusing point), the resistance suddenly increased. They carried the temperature to a still higher point than Hittorff had done, and found that the resistance again diminished, reaching a second minimum at 250° C.

During the course of their experiments they produced a variety of granular selenium not different in appearance from other specimens but having different electrical properties. In this form the resistance became greater instead of less when the temperature was raised.

They also used thin plates of selenium instead of the cylindrical bars formerly employed, and found great advantage from the increased sensitiveness of the former to light.

Sale found upon exposing selenium to the action of the solar spectrum that the maximum effect was produced just at or outside the extreme edge of the red end of the spectrum at a point nearly coincident with the maximum of the heat rays, thus rendering it uncertain whether the effect was due to light or to radiant heat.

In the winter of 1873–4 the Earl of Rosse‡ attempted to decide this question by comparing the selenium effects with the indications of the thermopile. He exposed selenium to the action of non-luminous radiations from hot bodies, but could produce no effect; whereas, a thermopile under similar conditions gave abundant indications of a current.

He also cut off the heat rays of low refrangibility from luminous bodies by the interposition of glass and alum between the selenium and the source of light without materially affecting the result; but when the thermopile was employed the greater portion of the heat-effect was cut off.

* Proc. Roy. Soc., xxi, 283; see also Pogg. Ann., cl, 333; Phil. Mag., IV, xlvii, 216; Nature, viii, 134.

† Proc. Roy. Irish Acad., II, Nov. 10th, 1873, 1, 529; see also a communication from Richard J. Moss to Nature, Aug. 12th, 1875, xii, 291; being an answer to a letter from J. E. H. Gordon upon the "Anomalous behavior of Selenium," published in that journal on the 8th of July, 1875; see vol. xii, p. 187.

‡ Phil. Mag., IV, March, 1874, xlvii, 161; see, also, this Journal, III, vii, 512.

Later, Prof. W. G. Adams,* of Kings College, took up the question, and his experiments seemed to prove conclusively that the action was due principally, if not entirely, to those rays of the spectrum which were luminous, and that the ultra-red or the ultra-violet rays had little or no effect.

This conclusion was supported by the marked effect produced by the light of the moon, and by the apparent insensitiveness of selenium to rays passed through a solution of iodine in bisulphide of carbon. He found that the maximum effect was produced by the greenish-yellow rays, and showed that *the intensity of the action depended upon the illuminating power of the light*, being *directly as the square root of that illuminating power.*

Professor Adams and Mr. R. E. Day† continued these researches, and among other interesting and suggestive results, discovered that light produces in selenium an electromotive force without the aid of a battery.

The most sensitive variety of selenium that has yet been produced was obtained in Germany by Dr. Werner Siemens, by continued heating for some hours at a temperature of 210° C., followed by extremely slow cooling.

Dr. C. W. Siemens,‡ in a lecture delivered before the Royal Institution of Great Britain, on the 18th of February, 1876, stated that his brother's modification of selenium was so sensitive to light that its conductivity was *fifteen times as great in sunlight as it was in the dark.*

In Werner Siemens'§ experiments special arrangements were made for reducing the resistance of the selenium.

For this purpose two fine platinum wires were coiled into a double flat spiral and were laid upon a plate of mica, so that they did not come into contact with one another. A drop of melted selenium was then placed upon the platinum wire arrangement and a second sheet of mica was pressed upon the selenium so as to cause it to spread out and fill the spaces between the wires. Each cell was about the size of a silver dime. The cells were then placed in a paraffine bath and annealed.

Siemens devised other arrangements of apparatus for reducing the resistance. In the form known as "Siemens' Grating," the

* Proc. Roy. Soc., June 17th, 1875, xxiii, 535; see, also, Proc. Roy. Soc., Jan. 6th, 1876, xxiv, 163; Nature, Jan. 20th, 1876, xiii, 238; Nature, Mar. 23d, 1876, xiii, 419: Scient. Amer. Supplement, June 3d, 1876, i, 354.

† Proc. Roy. Soc., June 15th, 1876, xxv, 113.

‡ Proc. Roy. Inst. Gt. Brit., Feb. 18th, 1876, viii, 68; see, also, Nature, xiii, 407; Scient. Amer. Supplement, Apr. 1st, 1876, i, 222; Scient. Amer. Supplement, June 10th, 1876, i, 375.

§ Monatsbericht der Kön. preuss. Akad. der Wissenschaften zu Berlin for 1875, p. 280; Phil. Mag., Nov. 1875, lV, l, 416; Nature, Dec. 9th, 1875, xiii, 112; Monatsber. Berl. Akad., Feb. 17, 1876; Pogg. Ann., clix, 117; Monatsb. Berl. Akad., June 7, 1877; Pogg. Ann., 1877, ii, 521.

two wires, instead of being coiled together, were arranged in a zig-zag shape, forming a sort of platinum gridiron.

This was treated in the same way as the spiral arrangement. Another form of cell consisted of a sort of lattice-work or basket-work of platinum wires arranged upon a perforated mica plate, the wires interlacing with one another, and with the mica plate so as to make metallic contact only with alternate wires. He also found that iron and copper might be employed, instead of platinum.

Without dwelling further upon the researches of others I may say that all observations concerning the effect of light upon the conductivity of selenium have been made by means of the galvanometer, but it occurred to me that the telephone, from its extreme sensitiveness to electrical influences, might be substituted with advantage. Upon consideration of the subject, however, I saw that the experiments could not be conducted in the ordinary way, for the following reasons: The law of audibility of the telephone is precisely analogous to the law of electric induction. No effect is produced during the passage of a continuous and steady current. It is only at the moment of change from a stronger to a weaker state, or, *vice versa*, that any audible effect is produced; and the amount of effect is exactly proportional to the amount of *variation* in the current.

It was, therefore, evident that the telephone could only respond to the effect produced in selenium at the moment of change from light towards darkness, or, *vice versa*, and that it would be advisable to intermit the light with great rapidity so as to produce a succession of changes in the conductivity of the selenium, corresponding in frequency to musical vibrations within the limits of the sense of hearing. For I had often noticed that currents of electricity, so feeble as hardly to produce any audible effects from a telephone when the circuit was simply opened and closed, caused very perceptible musical sounds when the circuit was rapidly interrupted; and that the higher the pitch of the sound the more audible was the effect. I was much struck by the idea of in this way producing sound by the action of light.

I proposed to pass a bright light through one of the orifices in a perforated screen consisting of a circular disc or wheel with holes near the circumference. Upon rapidly rotating the disc an intermittent beam of light would fall upon the selenium and a musical tone should be produced from the telephone, the pitch of which would depend upon the rapidity of the rotation of the disc.

Upon further consideration it appeared to me that all the audible effects obtained from variations of electricity could also

be produced by variations of light, acting upon selenium. I saw that the effect could not only be produced at the extreme distance at which selenium would normally respond to the action of a luminous body, but that this distance could be indefinitely increased by the use of a parallel beam of light, so that we might telephone from one place to another without the necessity of a conducting wire between the transmitter and receiver.

It was evidently necessary in order to reduce this idea to practice, to devise an apparatus to be operated by the voice of a speaker, by which variations could be produced in a parallel beam of light, corresponding to the variations in the air produced by the voice.

I proposed to pass light through a perforated plate containing an immense number of small orifices.

Two similarly perforated plates were to be employed. One was to be fixed and the other to be attached to the center of a diaphragm actuated by the voice; so that the vibration of the diaphragm would cause the movable plate to slide to and fro over the surface of the fixed plate, thus alternately enlarging and contracting the free orifices for the passage of light. In this way the voice of a speaker could control the amount of light passed through the perforated plates without completely obstructing its passage. This apparatus was to be placed in the path of a parallel beam of light, and the undulatory beam emerging from the apparatus could be received at some distant place upon a lens, or other apparatus by means of which it could be condensed upon a sensitive piece of selenium placed in a local circuit, with a telephone and galvanic battery.

The variations in the light produced by the voice of the speaker should cause corresponding variations in the electrical resistance of the selenium at the distant place, and the telephone in circuit with the selenium should reproduce audibly the tones and articulations of the speaker's voice.

I obtained some selenium for the purpose of trying the apparatus described; but found upon experiment that its resistance was almost infinitely greater than that of any telephone that had been constructed; and I was therefore unable at that time to obtain audible effects in the way desired. I believed, however, that this obstacle could be overcome by devising mechanical arrangements for reducing the resistance of the selenium, and by constructing special telephones for the purpose.

I felt so much confidence in this that in a lecture delivered before the Royal Institution of Great Britain, on the 17th of May, 1878, I announced the possibility of hearing a shadow by means of interrupting the action of light upon selenium. A

few days afterwards my ideas upon this subject received a fresh impetus by the announcement made by Mr. Willoughby Smith,* before the Society of Telegraph Engineers, that he had heard the action of a ray of light falling upon a bar of crystalline selenium by listening to a telephone in circuit with it.

It is not unlikely that the publicity given to the speaking telephone during the last few years, may have suggested to many minds, in different parts of the world, somewhat similar ideas to my own; indeed, it has recently come to my knowledge that a writer (J. F. W.,† of Kew) on the 13th of June, 1878, asked the readers of "Nature" through the columns of that periodical, whether any experiments had been made with a telephone in circuit with a selenium galvanic element arranged as in Sabine's selenium battery;‡ and suggested that it was not unlikely that sounds would be produced in a telephone by the action of light of variable intensity upon a selenium element in circuit with it.

In September or October, 1878, Mr. A. C. Brown, of London, submitted to me, confidentially, the details of a most ingenious invention of his, of which we may yet hear more. This invention, although entirely different from my own, involved the use of selenium in circuit with a battery and telephone, and the production of articulate speech by the action of a variable light. I am also aware that Mr. W. D. Sargent, of Philadelphia, has had some ideas of a similar nature, the details of which I do not know. I understood from Mr. Sargent that he proposed submitting selenium to the influence of an oscillating beam of light which should be sent on and off the selenium by the action of the voice. If this is so the effect produced would be only of an intermittent character and a musical tone, not speech, would be heard from the telephone in circuit with the selenium.

Although the idea of producing and reproducing sound by the action of light, as described above, was an entirely original and independent conception of my own, I recognize the fact that the knowledge necessary for its conception has been disseminated throughout the civilized world, and that the idea may therefore have occurred, independently, to many other minds.

I have stated above the few facts that have come under my observation bearing upon the subject.

The fundamental idea, on which rests the possibility of producing speech by the action of light, is the conception of what may be termed an undulatory beam of light in contra-distinction to a merely intermittent one.

By an undulatory beam of light I mean a beam that shines

* See Journ. of Teleg. Engin., May 23, 1878, vii, 284.
† Nature, xviii, 169. ‡ Nature, xvii, 512, Apr. 25, 1878.

continuously upon the receiver, but the intensity of which upon that receiver is subject to rapid changes corresponding to the changes in the vibratory movement of a particle of air during the transmission of a sound of definite quality through the atmosphere. The curve that would graphically represent the changes of light would be similar in *shape* to that representing the movements of the air. I do not know whether this conception had been clearly realized by J. F. W., of Kew, or by Mr. Sargent, of Philadelphia, but to Mr. A. C. Brown, of London is undoubtedly due the honor of having distinctly and independently formulated the conception and of having devised apparatus, though of a crude nature, for carrying it into execution.

It is greatly due to the genius and perseverance of my friend, Mr. Sumner Tainter, of Watertown, Mass., that the problem of producing and reproducing sound by the agency of light has at last been successfully solved. For many months past we have been devoting ourselves to the solution of this problem and I have great pleasure in presenting to you to-night the results of our labors.

Researches of Sumner Tainter and Alexander Graham Bell.

The first point to which we devoted our attention was the reduction of the resistance of crystalline selenium within manageable limits. The resistance of selenium cells, employed by former experimenters, was measured in millions of ohms, and we do not know of any record of a selenium cell measuring less than 250,000 ohms in the dark.

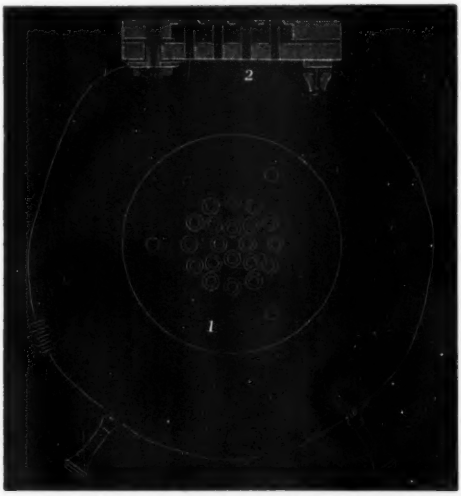
We have succeeded in producing sensitive selenium cells measuring only 300 ohms in the dark and 150 ohms in the light. All former experimenters seemed to have used platinum for the conducting part of their selenium cells, excepting Werner Siemens, who found that iron and copper might be employed. We have discovered that brass, although chemically acted upon by selenium, forms an excellent and convenient material; indeed, we are inclined to believe that the chemical action between the brass and selenium has contributed to the low resistance of our cells by forming an intimate bond of union between the selenium and brass.

We have observed that melted selenium behaves to other substances as water to a greasy surface, and we are inclined to think that when selenium is used in connection with metals not chemically acted upon by it, the points of contact between the selenium and the metal offer a considerable amount of resistance to the passage of a galvanic current, and thus serve to increase the apparent resistance of the selenium.

By using brass we have been enabled to construct a large

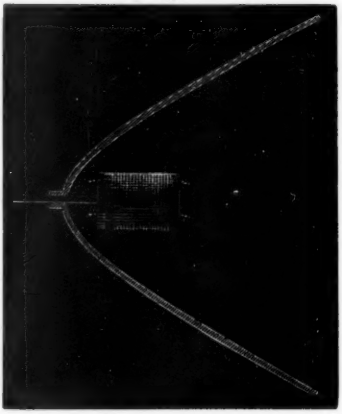
number of cells of different forms. Time will only admit of my showing you two typical forms. One of these is shown in plan in fig. 1, and in section in fig. 2.

1, 2.



This cell consists of two brass plates insulated from one another by a sheet of mica. The upper plate has numerous perforations and brass pins attached to the lower plate, pass through these orifices so that their ends without touching the upper plate are flush with its surface.

3.



The annular spaces between the pins and the plate are filled with selenium. The whole arrangement forms part of a galvanic circuit, and it will be observed that the current can only pass from the plate to the pins through the selenium rings.

It will also be seen that owing to the conical shape of the perforations the points of closest approximation between the pins and the plate are on the upper surface. As the effect produced by light upon selenium is chiefly a surface action, this arrangement is found to be of great advantage.

The second typical cell is cylindrical in form, for the purpose of being used with a concave reflector instead of with a lens (see fig. 3.)

This cell is composed of a large number of metallic discs separated by discs of mica slightly smaller in diameter. The spaces between the brass discs over the mica are filled with selenium, and the alternate brass discs are metallically connected. The arrangement practically consists of a large number of annular selenium cells united in mutiple arc.

The mode of applying the selenium is as follows:

The cell is heated, and when hot enough a stick of selenium is rubbed over the surface.

In order to acquire conductivity and sensitiveness the selenium must next undergo a process of annealing.

The method we first adopted was the following:

The selenium cell was placed with a thermometer in the interior of the cylindrical annealing chamber shown in fig. 4.

4.

B=battery; Sh=shunt; G=galvanometer.

This was inserted in a pot of linseed oil, and the latter stood upon glass supports within another similar pot containing linseed oil. The whole arrangement was then placed over a gas stove and heated to a temperature of about 214° C., which was found to be the temperature of maximum conductivity for the selenium used.

This temperature was retained for about twenty-four hours, and the pots, with their contents, were then packed in a box so arranged as to retard radiation of heat.

The selenium took from forty to sixty hours to cool down to the temperature of the air.

A powerful battery current was passed through the selenium during the whole process of heating and cooling, in accordance with our theory that the current exerted a powerful influence in causing a set of the selenium molecules, and in retaining them in position until fixed by crystallization.

A shunted galvanometer was introduced into the circuit for the purpose of observing the changes of conductivity. We subsequently found this tedious process to be unnecessary, as during the course of our experiments we discovered a method of preparing sensitive selenium in a very few minutes.

We now simply heat the selenium over a gas stove and observe its appearance. When the selenium attains a certain temperature, the beautiful reflecting surface becomes dimmed. A cloudiness extends over it, somewhat like the film of moisture produced by breathing upon a mirror.

This appearance gradually increases and the whole surface is soon seen to be in the metallic, granular, or crystalline condition. The cell may then be taken off the stove and cooled in any suitable way. When the heating process is carried too far, the crystalline selenium is seen to melt.

Our best results have been obtained by heating the selenium until it crystallizes as stated above, and by continuing the heating until signs of melting appear, when the gas is immediately put out.

The portions that had melted instantly re-crystallize, and the selenium is found upon cooling to be a conductor, and to be sensitive to light. The whole operation occupies only a few minutes. This method has not only the advantage of being expeditious, but it proves that many of the accepted theories on this subject are fallacious.

Early experimenters considered that the selenium must be "cooled from a fused condition with extreme slowness." Later authors agree in believing that the retention of a high temperature—short of the fusing point—and slow cooling—are essential, and the belief is also prevalent that crystallization takes place only during the cooling process.

Our new method shows that fusion is unnecessary, that conductivity and sensitiveness can be produced without long heating and slow cooling; and that crystallization takes place during the heating process. We had found that on removing the source of heat, immediately on the appearance of the cloudiness above referred to, distinct and separate crystals can be observed under the microcsope, which appear like leaden snow flakes on a ground of ruby red.

Upon removing the heat when crystallization is further advanced, we perceive under the microscope masses of these crystals arranged like basaltic columns, standing detached from one another—and at a still higher temperature the distinct columns are no longer traceable, but the whole mass resembles metallic pudding-stone with here and there a separate snow flake, like a fossil on the surface. Selenium crystals formed during slow cooling after fusion, present an entirely different appearance, showing distinct facets.

I must now endeavor to explain the means by which a beam of light can be controlled by the voice of a speaker.

Photophonic Transmitters.

We have devised upwards of fifty forms of apparatus for varying a beam of light in the manner required, but only a few typical varieties need be described.

(1st.) The source of light may be controlled, or (2nd) a steady beam may be modified at any point in its path.

In illustration of the first method we have devised several forms of apparatus founded upon Kœnig's manometric capsule, operating to cause variations in the pressure of gas supplied to a burner, so that the light can be vibrated by the voice.

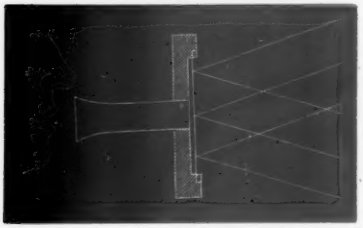
In illustration of the second method I have already shown one form of apparatus by which the light is obstructed in a greater or less degree, in its passage through perforated plates. But the beam may be controlled in many other ways. For instance, it may be polarized, and then affected by electrical or magnetical influences in the manner discovered by Faraday and Dr. Kerr.

Let a polarized beam of light be passed through a solution of bisulphide of carbon contained in a vessel inside a helix of insulated wire, through which is passed an undulatory current of electricity from a microphone or telephonic transmitter operated by the voice of a speaker.

The passage of the polarized beam should be normally partially obstructed by a Nicols prism, and the varying rotation of the plane of polarization would allow more or less of the light to pass through the prism, thus causing an undulatory beam of light capable of producing speech.

The beam of polarized light, instead of being passed through a liquid could be reflected from the polished pole of an electromagnet in circuit with a telephonic transmitter.

5.



Another method of affecting a beam of light is to pass it through a lens of variable focus* formed of two sheets of thin glass or mica containing between them a transparent liquid or gas. The vibrations of the voice are communicated to the gas or liquid, thus causing a vibratory change in the convexity of the glass surfaces and a corresponding change in the intensity of the light received upon the sensitive selenium. We have found that the simplest form of apparatus for producing the effect consists of *a plane mirror*

* I observe that a lens of similar construction has been invented in France by Dr. Cusco, and is described in a recent paper in "La Nature." See, also, Scien. Amer., Aug. 28, 1880, xliii, 131. Mr. Tainter and I have used such a lens in our experiments for months past.

of flexible material, such as silvered *mica or microscope-glass, against the back of which the speaker's voice is directed,* as shown in the diagram (fig. 5).

Light reflected from such a mirror is thrown into vibrations corresponding to those of the diaphragm itself. In its normal condition a parallel beam of light falling upon the diaphragm mirror would be reflected parallel. Under the action of the voice the mirror becomes alternately convex and concave, and thus alternately scatters and condenses the light.

When crystalline selenium is exposed to the undulatory beam reflected from such an apparatus, the telephone connected with the selenium audibly reproduces the articulation of the person speaking to the mirror.

In arranging the apparatus for the purpose of reproducing sound at a distance, any powerful source of light may be used, but we have experimented chiefly with sun-light.

For this purpose, a large beam is concentrated by means of a lens upon the diaphragm mirror and after reflection is again rendered parallel by means of another lens. The beam is received at a distant station upon a parabolic reflector, in the focus of which is placed a sensitive selenium cell, connected in a local circuit with a battery and telephone. We have found it advisable to protect the mirror by placing it out of the focal point, and by passing the beam through an alum cell, as shown in fig. 6.

6.

A large number of trials of this apparatus have been made with the transmitting and receiving instruments so far apart that sounds could not be heard directly through the air. In illustration I shall describe one of the most recent of these experiments.

Mr. Tainter operated the transmitting instrument, which was placed on the top of the Franklin School House in Washington, and the sensitive receiver was arranged in one of the windows of my laboratory, 1325 L Street, at a distance of 213 meters.

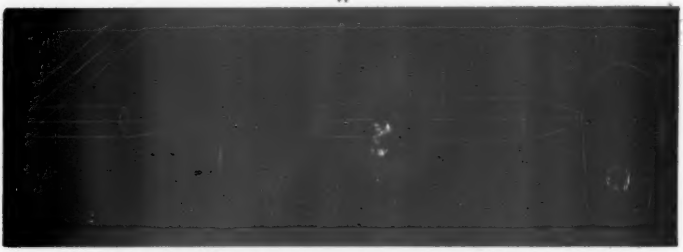
Upon placing the telephone to my ear, I heard distinctly from the illuminated receiver the words:—"Mr. Bell, if you hear what I say, come to the window and wave your hat."

In laboratory experiments the transmitting and receiving instruments are necessarily within ear-shot of one another, and we have therefore been accustomed to prolong the electric circuit connected with the selenium receiver, so as to place the telephones in another room.

By such experiments we have found that articulate speech can be reproduced by the oxyhydrogen light, and even by the light of a kerosene lamp. The loudest effects obtained from light are produced by rapidly interrupting the beam.

A suitable apparatus for doing this is a perforated disc which can be rapidly rotated. The great advantage of this form of apparatus for experimental work is the noiselessness of its operation, admitting of the close approach of the receiver without interfering with the audibility of the effect heard from the latter—for it will be understood that musical tones are emitted from the receiver when no sound has been made at the transmitter. A silent motion thus produces a sound. In this way musical tones have been heard even from the light of a candle.

7.



When distant effects are sought the apparatus can be arranged as shown in fig. 7.

By placing an opaque screen near the rotating disk the beam can be entirely cut off by a slight motion of the hand, and musical signals, like the dots and dashes of the Morse telegraph code, can thus be produced at the distant receiving station. Such a screen operated by a key like a Morse telegraph key is shown in fig. 8, and has been operated very successfully.

8.

Experiments to ascertain the nature of the rays that affect selenium.

We have made experiments with the object of ascertaining the nature of the rays that affect selenium. For this purpose we have placed in the path of an intermittent beam various absorbing substances.

Prof. Cross has been kind enough to give his assistance in conducting these experiments.

When a solution of alum, or bisulphide of carbon, is employed, the loudness of the sound produced by the intermittent beam is very slightly diminished, but a solution of iodine in bisulphide of carbon cuts off most, but not all, of the audible effect. Even an apparently opaque sheet of hard rubber does not entirely do this.

This observation, which was first made in Washington, D. C., by Mr. Tainter and myself, is so curious and suggestive that I give in full the arrangement for studying the effect.

9.

When a sheet of hard rubber, A, was held as shown in the diagram (fig. 9) the rotation of the disc or wheel B interrupted what was then an invisible beam, which passed over a space of several meters before it reached the lens C, which finally concentrated it upon the selenium cell, D.

A faint but perfectly perceptible musical tone was heard from the telephone connected with the selenium that could be interrupted at will by placing the hand in the path of the invisible beam.

It would be premature without further experiments to speculate too much concerning the nature of these invisible rays; but it is difficult to believe that they can be heat rays, as the effect is produced through two sheets of hard rubber having between them a saturated solution of alum.

Although effects are produced, as above shown, by forms of radiant energy which are invisible, we have named the apparatus for the production and reproduction of sounds in this way "the Photophone," because an ordinary beam of light contains the rays which are operative.

Non-Electric Photophonic Receivers.

It is a well known fact that the molecular disturbance, produced in a mass of iron by the magnetizing influence of an intermittent electrical current, can be observed as sound by placing the ear in close contact with the iron, and it occurred to us that the molecular disturbance produced in crystalline selenium by the action of an intermittent beam of light should be audible in a similar manner without the aid of a telephone or battery. Many experiments were made to verify this theory, but at first without definite results.

The anomalous behavior of the hard rubber screen alluded to above suggested the thought of listening to it also.

This experiment was tried with extraordinary success. I held the sheet in close contact with my ear while a beam of intermittent light was focussed upon it by means of a lens. A distinct musical note was immediately heard. We found the effect intensified by arranging the sheet of hard rubber as a diaphragm, and listening through a hearing tube, as shown in fig. 10.

10.

We then tried crystalline selenium in the form of a thin disc and obtained a similar but less intense effect.

The other substances, which I enumerated at the commencement of my address, were now successively tried in the form of thin discs, and sounds were obtained from all but carbon and thin glass.*

In our experiments, one interesting and suggestive feature was the different intensities of the sounds produced from different substances under similar conditions. We found hard rubber to produce a louder sound than any other substance we tried, excepting antimony and zinc; and paper and mica to produce the weakest sounds.

On the whole, we feel warranted in announcing as our conclusions that *sounds can be produced by the action of a variable light from substances of all kinds when in the form of thin dia-*

* We have since obtained perfectly distinct tones from carbon and thin glass.

phragms. The reason why thin diaphragms of the various materials are more effective than masses of the same substances, appears to be that the molecular disturbance produced by light is chiefly a surface action, and that the vibration has to be transmitted through the mass of the substance in order to affect the ear.

On this account we have endeavored to lead to the ear air that is directly in contact with the illuminated surface, by throwing the beam of light upon the interior of a tube; and very promising results have been obtained. Fig. 11 shows the arrangement we have tried. We have heard from interrupted sunlight very perceptible musical tones through tubes of ordinary vulcanized rubber, of brass, and of wood. These were all the materials at hand in tubular form, and we have had no opportunity since of extending the observations to other substances.*

11.

I am extremely glad that I have the opportunity of making the first publication of these researches before a scientific society, for it is from scientific men that my work of the last six years has received its earliest and kindest recognition. I gratefully remember the encouragement which I received from the late Professor Henry, at a time when the speaking telephone existed only in theory. Indeed, it is greatly due to the stimulus of his appreciation that the telephone became an accomplished fact.

I cannot state too highly also the advantage I derived in preliminary experiments on sound vibrations in this building from Professor Cross, and near here from my valued friend Dr. Clarence J. Blake. When the public were incredulous of the possibility of electrical speech, the American Academy of Arts and Sciences, the Philosophical Society of Washington, and the Essex Institute of Salem, recognized the reality of the results and honored me by their congratulations. The public interest, I think, was first awakened by the judgment of the

* A musical tone can be heard by throwing the intermittent beam of light into the ear itself. This experiment was at first unsuccessful on account of the position in which the ear was held.

very eminent scientific men before whom the telephone was exhibited in Philadelphia, and by the address of Sir William Thomson before the British Association for the Advancement of Science. At a later period, when even practical telegraphers considered the telephone as a mere toy, several scientific gentlemen, Professor John Pierce, Professor Eli W. Blake, Dr. Channing, Mr. Clark and Mr. Jones, of Providence, R. I., devoted themselves to a series of experiments for the purpose of assisting me in making the telephone of practical utility; and they communicated to me, from time to time, the results of their experiment with a kindness and generosity I can never forget. It is not only pleasant to remember these things and to speak of them, but it is a duty to repeat them, as they give a practical refutation to the often repeated stories of the blindness of scientific men to unaccredited novelties, and of their jealousy of unknown inventors who dare to enter the charmed circle of science.

I trust that the scientific favor which was so readily accorded to the Telephone may be extended by you to this new claimant—"*The Photophone.*"

ART. XXXV.—*A New Meteoric Iron from North Carolina;* by W. E. HIDDEN.

ON the 19th of July, 1879, Mr. Gray W. Harris, while out prospecting for gold, on his land near Lick Creek, Davidson County, N. C., found an unusually heavy stone of the size of a large pear, which he at first mistook for a specimen of iron ore. On attempting to break it he found that the stone would not break but was covered with a uniformly thick skin or crust which scaled off under repeated blows of the hammer.

After carefully removing all he could of this crust, there remained a pear-shaped mass of what appeared to him to be a pure metal. The color of the metal, developed by hammering, was *white*, and this led him to conclude that it was silver. This "nugget of silver," as he called it, soon had a wide notoriety among all the mining camps in the region.

This story, substantially as above related, reached me at Concord, N. C., in the autumn of 1879; my informants were the Messrs. Richard Eames, Jr. and Sr. They had seen the "nugget" and believed it to be iron, perhaps native iron; they had noticed that the "nugget" had what Mr. Eames, Jr., aptly termed "night sweats." Little beads of a yellowish fluid*

* These watery exudations I have myself noticed and found to consist of chloride of iron. W. E. H.

would gather upon its surface over night, which, if wiped away, would form again in the next twenty-four hours.

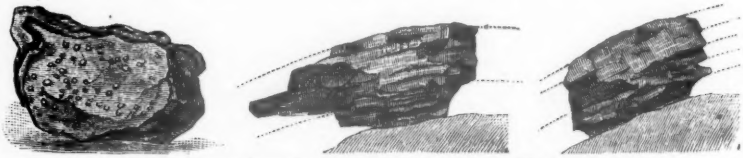
This last addition to the story of the "silver nugget" convinced me that the mass was really meteoric iron. After no little trouble and expense it was finally sent to Menlo Park, N. J., where it was at once recognized as *meteoric* iron. But for the active interest taken in this meteorite by the Messrs. Eames, it would have been in all probability lost to science; and I take this opportunity to express my indebtedness to them.

For the exact size and appearance of this meteorite see cut.*

Meteorite from Davidson County, North Carolina. (Exact size.)

* I am indebted to the "Illustrated Scientific News," of New York, for the use of this fine engraving. W. E. H.

It weighed when received here 1·24 kg., (= 2$\frac{3}{4}$ lbs.). Its outward color is *dark* brown, not rusty, and some little of the original crust yet adheres to it. The crust of this meteorite is of unusual importance and quite unique, as illustrated in the



Crust on Davidson County, N. C., Meteorite. (Exact size.)

accompanying figures. It averages 1^{cm} in thickness and resembles a hard, dark slate, shows a lamellar structure and readily breaks into flakes. Some cavities in this crust are lined with mammillary forms and it has many seams with a vitreous-like luster.

Last month I visited the spot where the meteorite was found and collected about six ounces of the crust. It lay there exactly as Mr. Harris had broken it off. I had no fears of mistake in identifying this crust as all the local gravel was composed of white quartz pebbles.

This iron has been analyzed by Dr. J. Lawrence Smith and J. B. Mackintosh, E.M. I here give the average of four closely agreeing analyses.

Iron, 93·00 per cent; nickel, 5·74 per cent; cobalt, 0·52 per cent; phosphorus, 0·36 per cent; traces of sulphur, chlorine and copper; carbon not determined. Total = 99·62 per cent. This iron does *not* show the customary Widmannstätten figures. I have etched all the exposed surfaces and obtained no well defined markings on a large scale, but I have found that the etched surfaces show crystalline faces which reflect the light at certain angles, giving a sort of sheen much like moonstone or labradorite. These reflecting surfaces are in parallel sets.

This is the second of the three *new* meteoric irons discovered in the Southern States, in the autumn of 1879, by the writer, who now holds in his possession the two already described in their original condition.

June 23, 1880.

ART. XXXVI.—*Results of Pendulum Experiments;* by C. S. PEIRCE, Assistant Coast and Geodetic Survey. [Published by authority of C. P. Patterson, Superintendent.]

THE following are the results obtained from observations made by me, for the U. S. Coast and Geodetic Survey, at four important stations, for the purpose of comparing the lengths of the seconds pendulum, together with reductions to the sea-level and to the equator. In making the last reduction I have assumed the ellipticity to be =1:293, which is the latest result from measurements of arcs.

	At station.	At sea-level.	At equator.
Hoboken	0·9932052^m	0·9932074^m	0·9910003^m
Paris	0·9939337	0·9939500	0·9910132
Berlin	0·9942399	0·9942482	0.9909865
Kew	0·9941776	0·9941790	0·9910083

The differences of the figures in the last column from 0·991^m, a value conveniently near their mean, when reduced to oscillations per diem are: Hoboken +0·01^s; Paris +0·58^s; Berlin −0·59^s; Kew +0·36^s. The following are the residuals of former observations according to Clarke (Geodesy, p. 349).

New York +0·20^s; Paris −3·29^s; Kew +2·89^s.

Colonel Clarke has used a value of the ellipticity =1:292·2 derived from pendulum experiments. This slight difference, however, is not important.

It should be explained that the result for Hoboken is derived from [T^2 Inv.] "Regular Set," given on page 318, and also on page 416 of the Report of the Superintendent of the U. S. Coast and Geodetic Survey for 1876. This number is treated as explained on page 319, where in the second line from the bottom for [T^2 Rev.] read [T^2 Inv.] The altitude of the Hoboken station is stated on page 204. The numbers for the European stations are copied from page 320.

The length which I have taken as the meter has been derived from the German Eichungsamt, as fully explained in my report. This is about 19·2 microns shorter than the quantity which is considered to be a meter in our own office of weights and measures, and is admitted in Berlin to be doubtful. It is impossible to fix the true meter at present; but I have but little doubt the above values will ultimately have to be diminished by about twenty microns on account of the error in the standard used.

SCIENTIFIC INTELLIGENCE.

I. Physics.

1. *Changes of volume produced by Electricity.*—Quincke sums up his results and those of other observers as follows: 1. Solid and fluid bodies change in volume when submitted like the glass of a Leyden jar to electrical force. 2. This change of volume does not arise from heating and is generally an expansion. In certain cases, however, it is a contraction, as for instance in the case of fat oils. 3. Quincke has not observed any change of volume in gases submitted to electrical influence. If a change takes place it must be smaller than $\frac{1}{3\,000\,000\,000}$ of the volume of air submitted to examination. 4. The change of volume is instantaneous in flint glass: but takes a longer time in Thüringian glass, which is a better conductor of electricity. Upon the discharge of the coatings of spherical or cylindrical formed condensers the glass resumes its original volume; this resumption is instantaneous in the case of flint glass, but slower with Thüringian glass. 5. The length of a cylindrical condenser alters at the same time that its volume changes. 6. The changes in volume and in length are greater the greater the difference of electrical potential and the less the thickness of the insulating substance of the condenser. 7. These changes are approximately proportional to the square of the ratio of the difference of potential and the thickness. These changes are different in different substances. 8. After the discharge of the coatings of the condenser a residual change of volume and length is observed. This effect is very small with flint glass, greater with Thüringian glass, and appears to depend upon the electric polarization of the mass of the glass. 9. The changes in volume and length do not arise from an electrical compression of the insulating substances. 10. In flint glass the electrical expansion is the same in all directions, and is independent of the kind and direction of the electricity. 11. Electrical changes of volume and length in glass increase with rising temperature in nearly the same proportion that the dielectric constant or the electric conductivity of glass increases. 12. Under the influence of electrical force the elasticity of flint glass, Thüringian glass, and caoutchouc diminishes, and that of mica and gutta percha increases. 13. The perforation of glass and other substances by electrical means results from unequal electrical dilatation at different points of the insulator. 14. By means of unequal electric expansion solid and fluid substances can be unsymmetrically dilated and be made doubly refracting, just as the unequal expansion of bodies by heat can effect the same result. 15. By means of electricity symmetrically dilated glass shows no electric double refraction. 16. The results of Dr. Kerr on positive and negative electrical double refraction depend on the manner in which the index of refraction in different substances changes with the density and the volume under electrical influ-

ence. 17. With a constant difference of potential between the coatings of a condenser, the electric strains in the successive layers of the substance between these coatings vary from time to time.—*Annalen der Physik und Chemie*, No. 8, 1880, p. 513.

J. T.

2. *A Phenomenon of Elasticity.*—If elastic gum is warmed, then expanded and wound in a spiral upon a glass tube or a wire and cooled for a short time in a cooling mixture, it shows no tendency to contract, but when it is submitted to hot water it returns quickly to its original length. This phenomenon can also be noticed without the use of the cooling mixture. If one holds heated gum a second in an expanded condition it shows no disposition to return to its original length; but if one immerses it in hot water it contracts to $\frac{1}{4}$ or $\frac{1}{5}$ and remains contracted to the third or fourth of its original length. Maxwell found similar phenomena in gutta percha, when this was submitted to expanding influences when in a cool condition. These are very marked phenomena of the secondary effects of elasticity.—*Proc. Edin. R. S.*, x, 1879, p. 52; *Beiblätter Annalen der Physik und Chemie*, No. 6, 1880, p. 422.

This property of rubber and gutta percha is significant in view of the recent experiments of Professor A. Graham Bell upon the effect of radiant energy upon thin discs of rubber. J. T.

II. Geology and Mineralogy.

1. *Moving snow-mass of Tuckerman Ravine, White Mountains, New Hampshire.*—Mr. W. H. Pickering gives the following account of an excursion, July, 1879, to this glacier-like snow-mass, in the number of "Appalachia" for June, 1880.

The walk from the Crystal Cascade through the ravine was uneventful, and in about three hours I reached the snow patch. Much of the snow had melted, so that some of the stones placed upon it were gone, but of those that remained the middle ones had moved about thirteen feet in twenty days, or at the rate of eight inches per day. The side ones had not apparently moved so fast. The surface of the snow was convex, being considerably higher at the middle. Where not exposed to the sun, the snow was very hard, and differed from ice only in color. The roof of the ice cavern was now quite high, and it could be entered for some fifty feet or more, although wading through ice-water in the dark may be considered more unusual than agreeable. From the above, it would appear that we have here the same glacial action that occurs on a much larger scale in the Alps, the same transportation, and therefore grinding, and polishing of the rocks, the same phenomena of viscosity and regelation; only that we here miss the long tongues of blue ice, with their accompanying crevasses. Our snow-patch, therefore, corresponds to the *névé*, or upper portion of a glacier, the whole of the lower portion being wanting. It might, perhaps, be called an incipient glacier.

2. *Notes on the Geology of the Iron and Copper Districts of Lake Superior;* by M. E. WADSWORTH. Cambridge, July, 1880. 158 pp. 8vo, with six plates. Bulletin of the Museum of Comparative Zoology at Harvard College, Vol. VII (Geological Series, Vol. I).—The author devotes 76 pages of his memoir to the iron district, 56 to the copper district, and 24 pages to a bibliography of his subject. Under each head a large part of the space is devoted to an historical review, giving the opinions and statements of authors in chronological order and largely by citations from their works. He quotes freely from the valuable Report on the Lake Superior District by Foster and Whitney, and in the main supports the views which Prof. Whitney had there brought out.

He makes the iron ores and associated beds of jasper *intrusive.*

The sandstones and conglomerates which accompany the trap in the copper region, and are more or less interstratified with it, owing to successive deposits and outflows as described by Whitney, are pronounced to be of the age of the Potsdam sandstone; but the conclusion is not based on the author's personal observations.

The kinds of copper deposits in the Portage Lake and Keweenaw Districts are stated to be as follows: 1st, The *amygdaloid*, in which the amygdaloidal rock contains bunchy and irregular deposits of copper which are in no sense veins or lodes. The Quincy and the Selden and Columbian Mines are examples; a variety of the Amygdaloid Mines, called in the region "ashbed" mines, are said to differ only in this that the amygdaloid is of a scoriaceous character. The Copper Falls and the Atlantic Mines are of this nature.

Besides these, there are, secondly, *Conglomerate* or true bed mines, like the Calumet and Hecla; and, thirdly, true *Fissure-vein* mines, like the Central, Phœnix and in part the Copper Falls.

In the Conglomerate mines, the beds of conglomerate have sometimes a cement of copper; and pebbles of trap appear occasionally to have been partly removed and to have had their places filled with copper. At the Calumet and Hecla mine, which is of this kind, the copper is found filling the joints of the overlying trap, and extending as a continuous sheet in fissures at right angles to one another.

At Copper Falls, "spikes of copper extend downward, out of the overhanging trap into the ashbed," or scoriaceous amygdaloid; and "these are generally large at the upper end and pointed at the lower." In the veins, the copper is found intimately mixed with the gangue, or in sheets or irregular masses; and the masses often enclose quartz, calcite and other kinds of vein materials, beside portions of the trap. "The farther from the sandstone and the nearer the heavy beds of trap, the larger have been the deposits of copper," as is exemplified at the Central, Cliff, and Calumet and Hecla mines.

The author holds that the copper and the associated minerals

of the veins and amygdules were deposited in the veins or cavities where now found by waters, from an external source after the sandstones, conglomerates and traps had been formed. He does not agree with Bowerman and Pumpelly that the copper was derived from the sandstone and thence carried down by hot or cold waters, but inclines to hold that the copper was originally finely disseminated through the lava at the time of its outflow, and has since been locally concentrated, by percolating waters, in veins, amygdules and conglomerate beds. While rejecting the theory of Professor Dana with regard to the origin of the copper deposits, he agrees with him, it thus appears, in the view that the copper came up with the trap, but disagrees in that he makes the present distribution of the copper, and also the filling of amygdaloidal cavities and veins by minerals, the *result of a subsequent process acting from above downward.*

The writer has regarded it, as he has long since explained,* an insuperable objection to the theory of infiltration from above, that surface waters can get into amygdaloids by means of infiltration downward only a short distance—in some not an inch; and that, however deep, the result caused by the waters and the accompanying air is oxidation and the discoloration and destruction of the rock.† Notwithstanding all that is brought forward by Mr. Wadsworth, or, rather, in view of these and other facts respecting trap minerals, I believe that the most satisfactory theory of the origin of the ores and associated minerals is that which I have hitherto held, only slightly modified: that the copper came up with the igneous rock, and so also the moisture that made the steam cavities of the amygdaloid, though neither was derived, the one nor the other, from the deep-seated source of the eruption, but from sources encountered on the way up; that, while the rock was slowly cooling through the range of temperatures from that of fusion, over 2000° F., to 212° F. (when at last the vapors began to lose their chemical activity), and thence to 100° F. and below, the igneous material sooner or later received its vapor-made cavities in places where the pressure was little enough to permit it and the moisture was abundant enough to produce them, and the rocks also became jointed and fissured through the progressing contraction; that other fissures may have been opened by new subterranean movements while the cooling was going forward, that is, before the era of eruptions for the region had passed, and gave passage for ascending vapors and whatever they bore along; that the moisture which made the

* This Journal, xlix, 49, 1845.

† The waters of hot springs might produce depositions in cavities or fissures that open upward; but it appears to be physically impossible that such waters, whatever they may hold in solution, should penetrate deeply through the mass of a cold trap or amygdaloid containing disseminated copper in grains, and take up and transport that copper into the amygdaloidal cavities, fissures, and joints. Surface waters sometimes descend for yards along the joints; but when so, the surfaces of the joints indicate it by their iron-rust discoloration. The gathering of copper from the adjoining sandstone into the trap cavities by such superficial waters seems to the writer to be not less impossible. J. D. D.

amygdaloidal cavities was the moisture which altered the pyroxene or other minerals of the rock to chlorite, and made the zeolites and quartz out of chiefly its feldspars, and that this kind of transformation of the igneous rock near all cavities or fissures into quartz and hydrous silicates kept going on as long as the rock was undergoing its refrigeration, different minerals resulting at different stages in the temperature; and that the copper which came up with the igneous rock was, in the course of the cooling, carried by the aid of the vapors into fissures and so formed veins, and into other cavities to help make amygdules at the same time that other minerals were making them, and so produced sometimes a cupriferous amygdaloid; and that simultaneously it was carried also to some extent into the adjoining sandstone. But all the conditions of the process are not yet explainable, and, therefore, while differing widely from the author on this and other points in his volume, I agree with him in this, that "until we know more about the occurrence of the copper, all theories regarding its origin should be held with a loose grasp, and dropped as the facts developed may require." J. D. D.

3. *Paleontological Notes;* by C. A. WHITE.—Professor White has notes, in the Proceedings of the United States National Museum, on the occurrence of *Productus giganteus* from an argillaceous rock of Carboniferous age in the valley of McCloud River, Shasta Co., California, one of them 5½ inches in transverse diameter near the hinge; on a new Cretaceous Pinna, *P. Stevensoni*, from near Fort Wingate, Northern New Mexico, and on the occurrence of two species of *Stricklandinia*, *S. Salteri* Billings, *S. Davidsoni* Billings, in the town of Ringgold, Catoosa Co., Georgia, where they were collected by Lieut. A. W. Vogdes, U. S. A. With regard to the last he says that the other fossils of this collection were doubtless correctly referred by Lieut. Vogdes (in this Journal, Dec. 1879, xviii, 475, 477), to the Clinton Group of New York; and their discovery in Georgia, if the identification is correct, has special interest because the two species have hitherto been found only in strata of the island of Anticosti, and also because these (with the associated fossils) indicate the equivalency of the Georgia, Clinton, and Anticosti strata in America, and the Upper Llandovery of Great Britain. Professor White also states that the Discina-like Brachiopod from the Primordial strata at Antelope Spring, Southern Utah, which he has described under the name of *Acrotreta subsidua*, "referring it to that genus provisionally," belongs to Linnarsson's new genus *Acrothele;* and he adds that it is not unlikely that some American species referred to *Discina* will be found to belong to this genus.

Professor White has also 180 pages of descriptions of fossils, and 32 plates, in the Twelfth Annual Report of the U. S. Geological Survey for 1878, under Dr. F. V. Hayden, which were issued in an "author's edition" in July last. The species described are from the Tertiary, Laramie, Cretaceous, Jurassic, Triassic, and Carboniferous groups. The Report is a continuation of his Contributions to Invertebrate Paleontology in the Report for 1877.

4. *Stratigraphical Geology of Eastern Ohio*, by Prof. EDWARD ORTON. 34 pp. 8vo. Columbus, Ohio, 1880.—The Report of the Secretary of State of Ohio for 1879 contains a paper by Professor Orton which gives the results of recent work by him in Eastern Ohio, leading to modifications of some views as to the stratigraphy of the region, and also bringing out some of the connections between the geological series of Ohio, Pennsylvania and Kentucky. A map of Eastern Ohio shows the outlines of the formations—the Berea Grit, the Lowest Coal, the Ferriferous limestone, Nelsonville Coal and Pittsburgh Coal. He observes, in conclusion, that the results as to the latter point, match so well with the facts arrived at in Pennsylvania by Professor White and Mr. Chance and others engaged in the survey of the western part of that State, that a number of the questions are settled. The paper closes with a table of equivalents between the Ohio strata and those of Pennsylvania and remarks upon it. "The key to the equivalencies is the Ferriferous limestone, which divides the Lower Coal Measures of Western Pennsylvania and of Southern Ohio alike."

5. *On the occurrence of Chalk in the New Britain Group;* by ARCHIBALD LIVERSIDGE. — In October last the Rev. G. Brown, Wesleyan missionary, brought, among other specimens, from New Britain and New Ireland (New Britain Group, latitude 4 degrees south, and 150 degrees east longitude) certain grotesque figures of men and animals, which had been carved by the natives of the above islands out of a soft white somewhat pulverulent material, having much the appearance of plaster of paris or chalk. Some of these figures were deposited in the museum, and a fragment broken off from one of them was placed in my hands for identification.

On examination, the remains of numerous Foraminifera are at once detected, the forms of the larger ones being plainly visible even to the unaided eye; under the microscope the whole mass of the rock is seen to be almost entirely composed of the shells and fragments of shells of Foraminifera, the remains of Globigerina being most abundant.

I took an early opportunity, when writing, to enclose a portion to Mr. H. B. Brady, F.R.S., of Newcastle-on-Tyne. He says:

"Your chalk from the New Britain group is a Cretaceous chalk, and not a friable Tertiary limestone. All the Foraminifera, or nearly so, are south Atlantic recent deep-sea species, *Globigerina bulloides*, *Gl. inflata*, *Pulvinulina Menardii* (a thick variety which I do not think is yet named), *P. Micheliniana*, and probably *P. Karsteni*, *Pullenia spheroides*, *Nonionina depressula*, *Bulimina Buchiana*, fragments of *Dentalina*, *Uvigerina*, etc.; also a characteristic *Pulvinulina* with thick shell and honeycombed surface, not yet described, of which I have quantities in the "Challenger" material.

The Rev. G. Brown wrote to me further as follows:—

"The chalk of which the figures are formed is, I am informed,

found only on the beach after an earthquake, being cast up there in large pieces by the tidal wave; and only, as far as we know at present, in one district on the east side of New Ireland."

An analysis shows that about 81 per cent of the specimen consists of calcium carbonate; thus it is undoubtedly a far less pure limestone than the ordinary white chalk. Its specific gravity is 2·199 at 59° F.—*Proc. of the Royal Society of New South Wales, July*, 1877.

6. *A new Theriodont Reptile.*—A new Theriodont from the Upper Permian sandstone near Orenburg in southeastern Russia has been described by W. H. Twelvetrees, in a paper read recently before the Geological Society of London. The beds rest on limestone which has the fossils of the Zechstein. Besides remains of Saurians and Labyrinthodonts, there are *Calamites*, *Lepidodendron*, *Conifers* and a *Unio*. The specimen is apparently the dentary part of the left mandibular ramus, with the crowns of a canine, an incisor, and ten of the molars. It is closely related to the genus *Rhopalodon;* but there are marked differences, and the author proposes to call it *Cliorhizodon Orenburgensis.*

7. *A new species of Iguanodon, I. Prestwitchii.*—The remains of this new species of Iguanodon are from the Kimmeridge clay, three miles west of Oxford. The skeleton was probably almost entire, but as the clay had been mostly removed before attention was directed to it many bones are lost. The discovery is the subject of a paper before the Geological Society of London, April 14th, by Prof. J. Prestwich. Prof. Prestwich's paper was followed by another by J. W. Hulke, Esq., describing the bones in detail and giving the species the above name.—*Quart. J. Geol. Soc.*, No. 143.

8. *The Geological Record for* 1877. An account of Works on Geology, Mineralogy and Palæontology published during the year, with Supplements for 1874–1876. Edited by Wm. Whittaker, B.A., F.G.S., of the Geological Survey of England. 432 pp. 8vo. London, 1880. (Taylor & Francis.)—This volume of the Record, like its predecessors, will be found of great value to geologists. The author has had a dozen or more able coadjutors in the preparation of the volume. Its several subdivisions are Stratigraphical and Descriptive Geology arranged according to countries; Physical Geology; Applied and Economic Geology; Petrology; Mineralogy; Paleontology; and Maps and Sections. The volume would be still more welcome if it could be issued nearer to the year of which it is a Record. We find in the preface, however, that great delay in the publication was caused "by the loss of MS. in transmission—the missing part (European Geology) having been appropriated by some very wise person as an article of great value, and not recovered for months."

9. *Orographie de la partie des Hautes-alpes Calcaires comprise entre le Rhone et le Rawyl* (Groupes des Diablerets et du Wildhorn), par E. Renevier, Professeur a la Faculté des Sciences

de Lausanne. 98 pp. 12mo. Lausanne, 1880.—This little book is the itinerary for 1880–81 of the Swiss Alpine Club. Besides being a contribution to Swiss orography and geology it is even more prominently a guide book to various passes in the Alps; and for this purpose all the details are given as to the routes, excursions, objects of interest, distances, guides, hotels, club-huts and other matters of importance to the traveler. The region lies between the transverse valley of the Rhone, (from Martigny to Lake Geneva) and the passage of the Rawyl (from Lenk to St. Leonard). The highest summit is that of the Diablerets, 3246 meters.

10. *On a "Fossil Glacier" of Yakutal Bay, Alaska;* by W. H. DALL.—Extract from a letter dated Unalaska, July 30th, from W. H. Dall, Assistant Coast and Geodetic Survey, in charge of the party on the coast of Alaska.

The most striking discovery made so far this season is that of what may perhaps properly be called a "fossil glacier" of colossal dimensions, situated on the northwest side of Yakutal Bay. This consists of the remains of an immense glacier, of which it would seem the feeders have either greatly diminished in size or entirely disappeared; leaving a sheet of ice on the plain below the mountains, spread over an area of fifty to seventy-five square miles, with little if any motion, and which by its own melting has become covered with a thick layer of mud, sand, gravel and stones. This layer protects the ice from the sun, and except in a few places the ice is quite invisible. In some spots, however, the ice seems to have melted beneath and the covering has fallen in, leaving a forest of immense ice pinnacles, each with a protective cap of dirt, and presenting a most extraordinary and almost indescribable appearance. The waste in these exposed spots is probably made up for by the snows of winter, and as the ice does not appear to have any motion, there seems to be no reason why it should not, like a layer of rock, endure to the end of time. This phenomenon offers an explanation of some previously inexplicable appearances in Kotzebue Sound, which have been a puzzle to geologists for forty years, and which, if opportunity offers, we may visit. Its geological importance is undeniable.

11. *Optical examination of the red feldspar of the granite from Lyme, Conn.*, by M. DESCLOIZEAUX.—At the close of the Paris Exposition of 1878, a fragment of the beautiful coarse granite from the McCurdy quarry at Lyme, Conn., was given by the Connecticut Commissioner, Prof. W. P. Blake, to M. DesCloizeaux, for optical study. Some details of his preliminary examination of its feldspar are given in the following translation from a letter, to Prof. Blake, of April 14, 1879. They disclose a fact of much mineralogical interest, which explains, as Mr. Blake remarks, the chatoyant reflections that give special beauty to the granite. "I have been able, lately, to examine your red feldspar from Lyme. It is a true microcline, but of an altogether peculiar structure, for the study of which the ordinary magnifying power

is not sufficient, the constituent parts being exceedingly minute. The face of easy cleavage shows a series of very small spots of albite, interspersed with hemitropic plates of microcline, the angle of extinction of which, not easily determined with great exactness, is 13° to 15° measured from the edge between the two cleavage-faces. Across the second cleavage the structure is as it were fibrous, and, with a high power, the angle of extinction is found to be from 7° to 9° for the microcline, and from 18° to 20° for the albite. I have never before met with a feldspar with the elements so crowded together and so fine. I hope you will yet be able to find, or that the proprietor will supply you with, some fragments of this beautiful granite. An examination of such specimens would be of great interest on account of the enormous size of its feldspar individuals."

III. Botany.

1. *The Native Flowers and Ferns of the United States;* by Thomas Meehan, illustrated by Chromo-lithographs. Series 2. Vols. I and II. Philadelphia: Chas. Robson & Co. 1880.—The last four parts of the issue of this series, now before us, if compared with the earlier show a great improvement in all respects. The drawings, and especially the chromo-lithography, the excellent typography, and the superfluously stout and high-calendered paper, combine to assure us that the editor has at length accomplished what he undertook, the production of attractive and characteristic illustrations of the U. S. Flora, accompanied by readable popular accounts of the plants, at a low price. The production of such a copious and discursive letter press to meet the demands of rapid serial publication is no light task, and it is not surprising if oversights now and then occur. Thus, under *Wyethia Arizonica*, which is remarkably well-figured, an account of Nuttall's crossing to the Pacific with Wyeth is given, in which it is said that this genus was not discovered on that route, but by Wyeth himself on the return trip. Now Nuttall's own publications and others show that Nuttall himself collected at least three species on his journey; and the date of the half-volume of the Academy's Journal, in which *Wyethia* was originally published, would show that this publication had taken place before Nuttall started upon that journey, and that the material was derived from an earlier expedition by Wyeth. If the readers of this work find it true that "Asters are not more difficult of study than other plants," (p. 159), their experience will be different from ours. *Heliopsis lævis* is not an "*Asteraceous* plant." As to the Compass-plant, it might be inferred that Longfellow's reference to "*this delicate plant*" preceded Gen. Alvord's account of it, "who seems to have been the first to direct scientific attention to the plant in 1848." Gen. Alvord's first account appeared in 1842, and was communicated to the poet. Under *Oxytropis Lamberti* (p. 191), why should it be said that Pursh seized on the labors of others and passed them off as his own? Pursh states

that he described from Bradbury's specimen (and this we believe is true), as well as from a living plant in Lambert's garden. In writing a flora of the country he could not have omitted it. That "Lambert, vice-President of the Linnean Society, was one of the most accomplished botanists of that time," was not the contemporary opinion. That he was, "indeed, the real editor of Pursh's work" is, we presume, a statement destitute of any foundation in fact. Good old Lambert used to say that he had great trouble in holding Pursh to his work, and had to shut him up for the purpose, during which Pursh "drank a whole barrel of beer." So that Pursh may properly, in his dedication, declare that the public has to thank his patron, Lambert, for the work, but surely not for editing it. A. G.

2. *Botany for High Schools and Colleges;* by CHARLES E. BESSEY, M.Sc., Ph.D., Professor of Botany in the Iowa Agricultural College, etc. New York: Henry Holt & Co. 1880. pp. 611, 12mo.—It speaks well for the progress of science in the United States, when a professor in a college in so new a State as Iowa, situated mid-way between the Mississippi and the Missouri, can produce so creditable a book as this. The work concerns itself throughout with what the Germans call "Scientific Botany,"—largely with vegetable anatomy and development, and with particular attention to the lower Cryptogamia. The plan in general is that of Sachs' *Lehrbuch*, the cuts of which are largely reproduced from electrotypes of the original blocks. The author says that his "book will thus, to a considerable extent, serve as an introduction to that work." It will indeed form a substitute for it; and the systematic part, so far as it goes, is an improvement upon the model. But that of itself would not be high praise, as this is the least valuable portion of the *Lehrbuch.* The figures from Sachs' blocks are good; but most of them were rather too large for his royal octavo page, and are out of proportion to the 12mo page in which they now appear. So, indeed, are some of the original ones. Some of the transfers from Maout and Decaisne have suffered in the process, although the paper and typography are excellent. Prof. Bessey's volume is a timely gift to American students of a good manual of vegetable anatomy and of the structure and classification of the lower cryptogamia, which was very much needed. Here at least is a commendable beginning. A. G.

3. *Manual of Swedish Pomology. Handbok i Svensk Pomologi* af OLOF ENENTH. Stockholm. Vols. I, II. 8vo. 1864, 1866.—We notice this for its admirable figures, both the woodcuts and the chromolithographs; ignorance of the language excuses from reference to the text. We have managed to surmount this obstacle in respect to an accompanying pamphlet, entitled

Bidrag till Europas Pomona vid dess Nordgräus.—This is an account of the trial of various European and North American varieties of apples and other fruits, with the object of determining

the northern limit at which they would come to perfection. This for twelve years of over 800 varieties yields results of general scientific as well as of local economical value. A. G.

IV. Miscellaneous Scientific Intelligence.

1. *Location of Lick Observatory on Mount Hamilton, California.*—In a report to the Trustees of the James Lick trust, Mr. S. W. Burnham gives the results of his observations made on Mt. Hamilton as to the location of the Lick Observatory. Mt. Hamilton is situated nearly east from San José, about twenty-six miles by the highway, but only thirteen in an air line. The approximate longitude of the Observatory peak is 121° 36′ 40″, and the latitude 37° 21′ 3″. The elevation of the point is 4,250 feet above the level of the sea, and 140 feet lower than the north peak which is about three-quarters of a mile distant. The view around is unobstructed, there being no higher ground within a radius of 100 miles. "The formation of Mt. Hamilton, as of all the near surrounding ridges, is of trap rock." Mr. Burnham's astronomical observations here reported had regard especially to the atmospheric conditions of the location with reference to its adaptation to observatory purposes. He states in his concluding remarks:

"So far as one may judge from the time during which these observations were made, there can be no doubt that Mt. Hamilton offers advantages superior to those found at any point where a permanent observatory has been established. The remarkable steadiness of the air, and the continued succession of nights of almost perfect definition, are conditions not to be hoped for in any place with which I am acquainted, and, judging from the published reports of the various observatories, are not to be met with elsewhere. The low altitude at which observations can be made is a matter of no small importance, particularly in connection with the portion of the southern sky not ordinarily accessible to observatories in the northern hemisphere. The ease with which difficult objects can be seen almost down to the horizon will be apparent from the southern declination of many of the new double stars. Close pairs can be observed at least down to 43° South Declination. The permanent steadiness of the air during the whole night will greatly increase the amount of telescopic work over what could ordinarily be done on good nights in most places. An examination of my observations at Chicago during the summer of the present year shows that the good seeing very rarely continued the whole night, even when it remained clear, and this has generally been the case heretofore. In many instances the conditions favorable for the observation of the most difficult objects would only last an hour or two, sometimes occurring in the first part of the night, and sometimes not commencing until after midnight. On Mt. Hamilton there is but little variation of any kind during the dry season. Each day was very much like every other day, and, as already shown, the same statement would apply equally well to the nights. Apparently there is but little to be

feared from the ocean fogs, as they seldom reach this elevation. Nearly every night, commencing at or soon after sunset, this fog comes in from the Pacific at the Golden Gate on the north, and the Bay of Monterey on the south, and covers the whole valley, between the base of Mt. Hamilton and the coast range, with a dense mass of vapor, resembling, when seen from above, a great white sea, the tops of the lower hills standing up through it like islands. Ordinarily it is perhaps 2,000 feet lower than the summit of Mt. Hamilton. It does not appear to have any effect on the seeing so long as it is below the summit."

He adds the following from a communication to him from Prof. George Davidson, of the United States Coast Survey:

"In the dry season the best observing is at the close of the wet season, say from March 1 to June or July. After that time the smoke of the great valley and the heated air on the San Joaquin side of the coast range, and the chilled air and strong winds on the ocean side, combine to give unfavorable conditions of seeing. I should not expect to get the best seeing in August and September, unless as an exceptional case.

"I should say that on the higher peaks of the Coast Range (over 3,000 feet), or in the Sierra Nevada, or on San Bernardino, at 10,000 feet, the astronomer may be sure of 250 good nights every year, and that 150 of those nights will be such as are rarely ever experienced at the east. The stars, the planets, the moon, the sun, and the nebulæ, are absolutely new presentations to the observer, and are capable of the most searching and minute measurements. Moreover, at the great heights, the thermometer will seldom fall below zero; and having weathered two Sierra storms of wind and snow at 10,600 feet, in a remarkably exposed situation, I am sure that an observatory would be as perfectly safe there as at lower elevations.

"There is of course more moisture in the atmosphere in the wet season; but when the sky clears up and the northerly wind blows, it is a dry wind, and the outlines of every thing visible are wonderfully sharp, distinct and steady. In October I could readily pick out the principal characteristics of the trees on Mocho (near Mt. Hamilton) at 120 miles."

Mr. Burnham closes his report with a catalogue of 42 new double stars discovered by him at Mt. Hamilton.

The Trustees announce that the observatory will soon be in working order. The small equatorial, ordered of Alvan Clark & Sons, will be placed in position early in 1881.

2. *Fiftieth Meeting of the British Association, at Swansea, Aug. 25th.*—Prof. RAMSAY, on taking the Presidential chair, gave his inaugural address. His subject was "The recurrence of certain phenomena in geological time," and his chief object, as he states, was to show that all known formations are comparatively so recent in geological time that there is no reason to believe they were produced under physical circumstances differing, either in time or degree, from those with which we are now more

or less familiar,—which is the doctrine of uniformitarianism as taught by Lyell. In reference to this point he reviews facts with regard to metamorphism in various geological ages; volcanoes; the formation of mountains; formation of salt and salt lakes; the occurrence of fresh water deposits in various ages and glacial phenomena of different periods. Under the head of metamorphism he states that presumed Cambrian and also to some extent Lower Silurian rocks in Anglesey have been metamorphosed into chlorite schist, mica schist and gneiss; that as Prof. Hull had shown, the close of the Lower Silurian was the epoch of the greatest metamorphism in Ireland; that Silurian and Devonian rocks in Cornwall are converted into mica schist and gneiss; and refers to examples of metamorphism of Mesozoic and Eocene rocks in the Alps and Cretaceous in South America. Under Glacial phenomena, he refers to evidence, which he regards as good, of glacier action, in *roche moutonnée* surfaces over granite, preceding the Cambrian in northwest Scotland; and of glacier-transported bowlders in the Lower Silurian of Wigtonsshire and Ayrshire; in the Upper Silurian of the Lammermuir Hills; in Permian beds of England, Germany, South Africa and India; in Cretaceous beds of the Salt range in India, and in Miocene deposits in the north of Italy, near Turin. Facts are presented also under the other heads; the degree of uniformitarianism which Professor Ramsay advocates appears to require for its satisfactory demonstration a much wider range of them than he appeals to.

The opening address before the Geological section, by its President, H. C. Sorby, treats of the comparative structure of artificial slags and eruptive rocks; that of the Biological section, by Dr. Gunther, of museums, their use and improvement; that of Professor W. Grylls Adams, President of the Section of Mathematics and Physics, gives a review of recent deductions in molecular physics; and that of F. M. Balfour, Vice-President of the department of Anatomy and Physiology, traces the influence of the Darwinian theory on embryology.

The following paragraphs are from the address of Professor Adams, *on the molecular constitution of matter in the solid, liquid, and gaseous states.*

"We have become accustomed to regard matter as made up of molecules, and those molecules to be made up of atoms separated from one another by distances which are great in comparison with the size of the atom, which we may regard as the smallest piece of matter that we can have any conception of. Each atom may be supposed to be surrounded by an envelope of ether which accompanies it in all its movements. The density of the ether increases rapidly as an atom is approached, and it would seem that there must be some force of attraction between the atom and its ether envelope. All the atoms have motions of translations in all possible directions, and according to the theories of Maxwell and Boltzmann, and the experiments of Kundt, Warburg, and others on the specific heat of vapors, in *one-atom* molecules in the

gaseous state there is no motion of rotation. According to the theory of Pictet, the liquid state, being the first condensation from the gaseous state, must consist of at least two gaseous atoms combined. These two atoms are bound to one another through their ether envelopes. Then the solid state results from the condensation of a liquid, and so a solid molecule must consist of at least two liquid molecules, i. e. at least four gaseous molecules, each surrounded by an atmosphere of ether. M. Pictet imagines these atoms to be centers of attraction; hence in the solid with four such centers the least displacement brings into action couples tending to prevent the molecule from twisting as soon as external forces act upon it. All the molecules constituting a solid will be rigidly set with regard to one another, for the least displacement sets in action a couple or an opposing force in the molecules on one another.

Let us now follow the sketch which M. Pictet has given of changes which we may consider it to undergo when we expend energy upon it. Suppose a solid body is at absolute zero of temperature, which may be regarded as the state in which the molecules of a body are in stable equilibrium and at rest, the application of heat gives a vibratory motion to the molecules of the solid, which increases with the temperature, the mean amplitude of vibration being a measure of the temperature. We may regard the sum of all the molecular forces as the specific heat of the body, and the product of the sum of all the molecular forces by the mean amplitude of the oscillations, i. e. the product of the specific heat and the temperature, will be the quantity of heat or the energy of motion of the body. As more and more heat is applied, the amplitude of vibration of the molecules increases until it is too great for the molecular forces, or forces of cohesion, and the melting point of the solid is reached. Besides their vibratory motion, the molecules are now capable of motions of translation from place to place among one another. To reduce the solid to the liquid state, i. e. to make the amplitude of vibration of the molecules sufficient to prevent them from coming within the sphere of the forces of cohesion, requires a quantity of heat which does not appear as temperature or molecular motion, and hence it is termed the latent heat of fusion. The temperature remains constant until the melting is complete, the heat being spent in bursting the bonds of the solid. Then a further application of heat increases the amplitude of vibration, or raises the temperature of the liquid at a rate depending on its specific heat until the succession of blows of the molecules overcomes the external pressure and the boiling-point is reached. An additional quantity of heat is applied which is spent in changing the body to a gas, i. e., to a state of higher potential, in which the motion of translation of the molecules is enormously increased. When this state is attained, the temperature of the gas again begins to increase, as heat is applied, until we arrive at a certain point, when dissociation begins, and the molecules of the separate sub-

stances of which the body is composed have so large an amplitude of vibration that the bond which unites them can no longer bring them again into their former positions. The potential of the substances is again raised by a quantity which is proportional to its chemical affinity. Again, we may increase the amplitude of vibration, i. e., the temperature of the molecules, and imagine the possibility of higher and higher degrees of dissociation."

Professor Balfour remarks as follows on the *development of organs of vision.*

"Another important fact shown by embryology is that the central nervous system, and percipient portion of the organs of special sense, are often formed from the same part of the primitive epidermis. Thus, in ourselves and in other vertebrate animals the sensitive part of the eye, known as the retina, is formed from two lateral lobes of the front part of the primitive brain. The crystalline lens and cornea of the eye are, however, subsequently formed from the skin.

The same is true for the peculiar compound eyes of crabs or Crustacea. The most important part of the central nervous system of these animals is the supraœsophageal ganglia, often known as the brain, and these are formed in the embryo from two thickened patches of the skin at the front end of the body. These thickened patches become gradually detached from the surface, remaining covered over by a layer of skin. They then constitute the supraœsophageal ganglia; but they form not only the ganglia, but also the rhabdons or retinal elements of the eye—the parts in fact which correspond to the rods and cones in our own retina. The layer of epidermis or skin which lies immediately above the supraœsophageal ganglia becomes gradually converted into the refractive media of the crustacean eye. A cuticle which lies on its surface forms the peculiar facets on the surface of the eye, which are known as the corneal lenses, while the cells of the epidermis give rise to lens-like bodies known as the crystalline cones.

It would be easy to quote further instances of the same kind, but I trust that the two which I have given will be sufficient to show the kind of relation which often exists between the organs of special sense, especially those of vision, and the central nervous system. It might have been anticipated *à priori* that organs of special sense would only appear in animals provided with a well-developed central nervous system. This, however, is not the case. Special cells with long delicate hairs, which are undoubtedly highly sensitive structures, are present in animals in which as yet nothing has been found which could be called a central nervous system; and there is every reason to think that the organs of special sense originated *pari passu* with the central nervous system. It is probable that in the simplest organisms the whole body is sensitive to light, but that with the appearance of pigment-cells in certain parts of the body, the sensitiveness to light became localized to the areas where the pigment-cells were pres-

ent. Since, however, it was necessary that stimuli received by such organs should be communicated to other parts of the body, some of the epidermic cells in the neighborhood of the pigment-spots, which were at first only sensitive, in the same manner as other cells of the epidermis, became gradually differentiated into special nerve-cells. As to the details of this differentiation, embryology does not as yet throw any great light; but from the study of comparative anatomy there are grounds for thinking that it was somewhat as follows:—cells placed on the surface sent protoplasmic processes of a nervous nature inwards, which came into connection with nervous processes from similar cells placed in other parts of the body. The cells with such processes then became removed from the surface, forming a deep layer of the epidermis below the sensitive cells of the organ of vision. With these cells they remained connected by protoplasmic filaments, and thus they came to form a thickening of the epidermis underneath the organ of vision, the cells of which received their stimuli from those of the organ of vision, and transmitted the stimuli so received to other parts of the body. Such a thickening would obviously be the rudiment of a central nervous system, and it is easy to see by what steps it might become gradually larger and more important, and might gradually travel inwards, remaining connected with the sense-organ at the surface by protoplasmic filaments, which would then constitute nerves. The rudimentary eye would at first merely consist partly of cells sensitive to light, and partly of optical structures constituting the lens, which would throw an image of external objects upon it, and so convert the whole structure into a true organ of vision. It has thus come about that, in the development of the individual, the retina or sensitive part of the eye is first formed in connection with the central nervous system, while the lenses of the eye are independently evolved from the epidermis at a later period."

3. *American Association for the Advancement of Science, Boston Meeting, August* 25 *to September* 1, 1880.—The twenty-ninth meeting of this Association, held at Boston, was by far the most numerously attended session in its history; and judged by the number and quality of the papers presented, the important matters brought out in the public addresses, and the numbers of interested auditors in the several sections, we must conclude that it had a scientific value never before equalled. The arrangements of the Local Committee were so thorough that all the machinery of the meeting moved smoothly, and completely met the numerous wants of such an occasion.

The Institute of Technology, and the Boston Natural History buildings, afforded ample and convenient space for all the sections, and a large hall (Huntington Hall) for the public sessions.

The badge of gold-colored ribbon, worn by members, gave admission to all the public places in Boston, and ensured courteous treatment everywhere. Free luncheons of the most tasteful and ample character were served daily in the Gymnasium

adjoining the Institute, and thus the members enjoyed an agreeable social reunion for the hour at noon, and were saved fatigue and loss of time.

The number of persons registered to the close of the meeting was very nearly one thousand—(979 to Tuesday evening, Aug. 31.) The number of papers entered was 280, and 595 new members were elected. The officers of the Association were in telephonic communication with all parts of Boston and the adjacent country; and members had, free of charge, the use of this facility as well as of the lines of the Western Union Telegraph Company for all scientific and domestic purposes, over the whole country. Among the many good deeds of the Local Committee, should be mentioned the distribution among the members of a map of Boston and its vicinity, and of a pamphlet containing "A brief account of the Scientific Institutions of Boston and vicinity, and a General Guide to the Museum of the Boston Society of Natural History," prepared by the custodian, Mr. Hyatt.

The meeting was under the Presidency of Mr. LEWIS H. MORGAN, of Rochester, N. Y., widely known for his Archæological investigations and memoirs.

The proper work of the Association commenced at 10 o'clock on Wednesday morning. Prof. Wm. B. Rogers, President of the Institute of Technology, welcomed the Association in a brief and graceful address; a welcome, renewed on behalf of the city of Boston by Mr. Frederick O. Prince the Mayor, and for the Commonwealth of Massachusetts by His Excellency Governor Long, to all of which President Morgan made a brief reply. After notices of members of the Association deceased during the year by the Secretary, the Association adjourned for the organization of the two Sections, A and B, and the Subsections of Chemistry, Microscopy and Anthropology. The Chairmen of the latter were, respectively, John M. Ordway of Boston, S. A. Lattimore of Boston, and J. W. Powell of Washington.

No papers were read on Wednesday. In the afternoon, at the meeting of the Physical Section, Mr. ASAPH HALL, Vice-President of the Section, gave his opening address, treating wisely of the best methods and chief objects of Astronomical research; and in the evening the Association, in General Session, listened to the address of the retiring President, Professor GEO. F. BARKER, "On some modern aspects of the Life-question," which held a large audience with interested attention for an hour.

The whole of Thursday, August 26, was given to Cambridge. At 11 o'clock, in Sander's Theatre of Harvard University, an excellent eulogy of the late Professor JOSEPH HENRY, was delivered by Alfred M. Mayer; and this was followed by the learned address of the Vice-President of Section B, ALEXANDER AGASSIZ, which will be found reproduced at length in these pages.

After these addresses the members, by invitation of the President and Fellows of Harvard College, dined, to the number of about 900, in Memorial Hall, one of the most extensive and beau-

tiful dining halls in the world. The afternoon was given up to the Museums, Libraries and Laboratories, and the evening to a garden party and reception, by Professor and Mrs. Gray, at the Botanic Gardens, and a visit to the Observatory, where the members were received by Professor and Mrs. Pickering, and the evening to a reception at the residence of Mr. and Mrs. A. Graham Bell.

The evening of Friday was devoted to a General Session to hear the paper by Mr. Bell, on his new apparatus, the *Photophone*, a subject of great general as well as scientific interest.

On Saturday afternoon the Association enjoyed the sail down Boston harbor, as the guests of the City of Boston, about one thousand persons being present. It is quite impossible to follow the Association in detail through all it had to enjoy at the hands of the good people of Boston. There were excursions to Salem, with visits to the Museum there, and the liberal hospitality of Mr. Endicott Peabody; a Geological excursion to Marble Neck; visits to Lowell, and many other places.

On Monday, after the close of the meeting, came the excursion to the White Mountains, for which arrangements had been made by the Appalachian Club. Thanks to the liberality of the Eastern Railroad, free tickets were supplied for three hundred members.

The Association adjourned on Wednesday to meet at Cincinnati, under the Presidency of Professor GEORGE J. BRUSH, of the Sheffield Scientific School of Yale College.

The following is a list of the Papers accepted:

1. *Mathematics, Physics, Astronomy and Meteorology.*

H. S. PRITCHETT: Determination of the rotation-time of Jupiter, from observations of the red spot in 1879–80, together with the physical character and changes of the spot.

W. A. NORTON: The force of effective molecular action, and the mechanical laws and properties dependent upon it; Determination of the comparative dimensions of ultimate molecules, and deduction of the specific properties of substances.

B. J. JEFFRIES: Color-blindness.

W. FERRELL: Maxima and minima tide-predicting machine.

C. J. H. WOODBURY: Friction of lubricating oils.

T. HILL: Problems in Watson's coördinates.

T. CRAIG: Steady and vortex motion in viscous incompressible fluids.

W. H. BALLOU: Improvement of the Mississippi River.

C. A. YOUNG: Spectroscopic notes, being a notice of certain spectroscopic observations, principally solar, made in 1879–80.

J. TROWBRIDGE: Heat produced by magnetising and demagnetising iron and steel.

S. E. WARREN: Some observations on geometric beauty, as founded on angular rather than linear ratios.

W. A. ANTHONY: Lecture experiment for the direct determination of the velocity of sound.

W. A. ROGERS: Progress made at the Observatory of Harvard College in the determination of the absolute coördinates of 109 fundamental stars; A simple and expeditious method of investigating all the division errors of a meridian circle; The systematic errors of the Greenwich right ascensions of southern stars observed between 1816 and 1831; Preliminary determination of the equation between the British imperial standard yard and the meter of the archives; The probable error of a single observation at sea, deduced from the observations of W. H. Bacon, Cunard steamer "Scythia;" The errors of a few English, French and American stage micrometers.

W. BOYD: A new Morse-alphabet.

B. PEIRCE: Unity, inversion, and semi-inversion in linear associative algebra; Useful practical forms of linear associative algebra; Comets of minimum perihelion distance; Cooling and possible age of the sun; Cooling and possible age of the earth.

D. P. TODD: Speculative and practical search for a trans-neptunian planet.

EDW. W. MORLEY: Remarks on tables for the reduction to zero of the measured volumes of gases; The most convenient scale for a thermometer used in gas analysis.

E. C. PICKERING: New planetary nebulæ.

C. R. CROSS and W. T. MILLER: On the musical pitch at present in use in Boston and vicinity.

S. W. HOLMAN: The use of the mercurial thermometer at high temperatures.

L. WALDO: Methods in use at the Observatory of Yale College for the verification of thermometers, and the testing of time-pieces.

E. L. NICHOLS and A. W. WHEELER: The coefficient of expansion of gas solutions.

E. H. HALL: The new action of magnetism on a permanent electric current.

T. R. BAKER: An investigation of the vibrations of plates vibrated at the center.

J. D. WARNER: Theory of the tides.

H. C. LEWIS: Note on the Zodiacal light; The Aurora and Zodiacal light of May 2, 1877.

F. H. LOUD: Discussion of the barometric observations of Professor E. S. Snell, Amherst College.

C. S. HASTINGS: A comparison of the spectra of light from limb and center of sun.

A. S. CARHART: A simple device for projeting vibrations of a liquid film without a lens.

GEO. W. HOLLEY: Suggestions for improvement in the manufacture of glass, and of new methods for the construction of large telescopic lenses.

J. R. BLAKE: Observations on some recent hail storms in North Carolina.

S. WELLS: Apparatus used in photographing microscopical objects.

F. E. NIPHER: Results of a magnetic survey of Missouri.

H. MORTON and B. F. THOMAS: Observations on the electro-motive force of the Brush dynamo-electric machine.

H. MORTON: Observations on the displacement of absorption bands in solutions of Purpurine.

A. G. BELL and S. TAINTER: Upon the production of sound by light.

W. HAILES: A new freezing microtome.

W. A. ANTHONY: A lecture experiment, showing the movement of a horizontal current in the earth's magnetic field; A proposed improvement in the construction of the Gramme electric machine.

R. H. RICHARDS: A gauge for measuring the pressure of liquids and gases.

A. M. MAYER: On the spectral rays which act in forming the green color in the leaves of plants; The topophone: an instrument to determine the direction and position of a source of sound, with an account of the applications of this instrument to scientific investigation; The uses of the "chungkee-stone;" On monuments of physical constants; A simple means of measuring the angle of inclination of the mirrors used in Fresnel's experiments on the interference of light; The determination of the velocities of fowling-piece shot, with remarks on the applications of these experiments to the art of shooting on the wing; A new method of obtaining a permanent trace of the plane of oscillation of a Foucault pendulum.

E. FRISBY: Symmetrical Equations.

S. C. CHANDLER, JR.: Two new instruments for the determination of time and latitude.

A. E. DOLBEAR: On the limits of visibility with the microscope; On some needed additions to physical terminology.

J. R. EASTMAN: The solar parallax for meridian observation of Mars in 1877.

O. STONE: On a continuation of Argelander's Durchmusterung; On the construction of a micrometer for double star observations; On the drawing of nebulæ; On uniform time.

C. J. BLAKE: A standard logograph.

R. H. THURSTON: Experiments on strength of yellow pine timber.

C. A. YOUNG: The thermoelectric electro-motive power of iron and platinum in vacuo.

E. B. ELLIOTT: Electric lighting as applied to large areas.

A. W. WRIGHT: On a form of vacuum tube for spectroscopic work; On the refractive index of metallic silver.

E. S. HOLDEN: On some of the consequences of an hypothesis proposed by Professor Pickering, that the intrinsic brilliancy of the fixed stars is the same for each star.

E. P. AUSTIN: A table of remainders of 2^n to various prime moduli.

F. H. BAILEY: The astral lantern.

GEO. W. COAKLE: Tidal theory of the forms of comets.

H. A. ROWLAND: Remarks on C. S. Peirce's paper on the ghosts in Rutherfurd's grating.

J. D. WARNER: New method for finding the numerical roots of equations below the 4th degree; "Actio in distans" and its effects.

WM. HARKNESS: On the color correction of achromatic telescope: On the spectroscopic measurement of the approach or recession of stellar objects.

N. D. C. HODGES; Maxwell's law of the distribution of velocities among gas molecules.

L. P. KENNICUTT: Substitution of cones made from parchment paper for platinum cones in Bunsen's process of filtration.

2. *Chemistry.*

A. N. LEEDS: Laws governing the decomposition of equivalent solutions of iodides under the influence of actinism, and their application to the actinometry of solar, electric and magnesium light; Action of sun-light in the production of chlorinated addition-products of Benzene and Naphthalene, with descriptions of two new chlorine derivatives of Naphthalene; Action of hyponitric anhydride upon organic substances, with descriptions of three new oxygenated derivatives of the aromatic group—Monoxybenzene, Tetroxynaphthalene and Naphthodiquinene.

C. F. GISSLER: Evidences of the effect of chemico-physical influences in the evolution of branchipod crustaceans.

T. GAFFIELD: Action of sunlight on glass.

E. T. COX: Oxide of antimony found in extensive lodes, in Sonora, Mexico.

N. B. WEBSTER: On a solution of ferric gallate and ferric oxalate as a reagent for quantitative analysis of ammonia.

EDW. W. MORLEY: Remarks on Jolly's apparatus for determining the amount of oxygen in air; Some points in the construction of an apparatus for the accurate analysis of gases; Numerical results for the mean ratio of oxygen to the sum of oxygen and nitrogen in atmospheric air; Some conclusions as to the causes of the frequent fluctuations in the ratio of oxygen to nitrogen in the air at different times.

F. W. CLARKE and HELENA STALLO: Constitution of the tartrates of antimony.

J. L. KLEINSCHMIDT: Foreign substances in iron.

H. W. WILEY: Optical properties of commercial starch and glucose.

L. M. NORTON: The valuation of indigo.

W. O. ATWATER: The chemical composition and nutritive values of fish; The soil supply of nitrogen for plants; Some new forms of apparatus; The determination of phosphoric acid by the molybdic process; The determination of sulphuric acid; The determination of nitrogen by the hypobromite process; The quantitativs determination of fats.

E. G. LOVE: On the illuminating gas of New York City.

W. R. NICHOLS: Observations on the temperature and chemical character of the water of Mystic Lake, Mass., at different depths.

C. F. MABERY and Mrs. R. LLOYD: The substituted acrylic acids.

E. L. NICHOLS: Salt solutions and the absorption of gases.

H. B. NASON: Notice of incrustations formed in pipes used in gas wells.

C. E. MUNROE: On the action of vegetable acids on tin; A modification of Berthier's method for the valuation of coal.

S. P. SHARPLES: Commercial testing of sugar, illustrated by samples of sugar and instruments used.

A. A. BRENEMAN: New colors for salt-glazed pottery; Notes on water analysis.

H. W. WILEY: Influence of heating with dilute acids and shaking with bone coal on rotatory power of glucose.

W. COLEGROVE: Direct combination of hydrogen and nitrogen.

IRA REMSEN: Formation of sulphoterephthlalic acid by direct oxidation.

G. F. KUNZ: Density of a large diamond.

3. *Geology and Mineralogy.*

J. W. DAWSON: The Pulmonates of the Paleozoic period.

N. H. WINCHELL: The Cupriferous series in Minnesota.

W. J. BEAL: Distinguishing species of Populus and Juglans by the young naked branches.

W. A. STEARNS: Iron mines of Ore Hill, Conn., and vicinity, and the making of pig iron.

GEO. H. STONE: Kames or Eskars of Maine.

A. A. JULIEN: The excavation of the upper basin and clove of the Kaaterskill, Catskill Mountains, N. Y.

G. F. WRIGHT: Condition of the kames and moraines of New England, as bearing upon the date of the glacial epoch.

E. S. MORSE: Japanese caves.

F. C. HILL: Fossil Dinocerata in the E. M. Museum at Princeton, N. J.

R. OWEN: Law of land forming on our globe.

W. BOYD: The Island of Montreal, an island in the Ottawa.

L. W. BAILEY: Progress of geological investigation in New Brunswick, 1870–1880.

W. H. NILES: Classification of mountains.

J. W. PIKE: Preservation of fossil insects and plants at Mazon Creek.

G. W. HAWES: The granites in the White Mountain Notch, upon Mount Willard, and their contact phenomena.

A. S. TIFFANY: Subsidence and erosion.

H. C. LEWIS: The tertiary age of the iron ores of the lower silurian limestone valleys.

M. E. WADSWORTH: The age of the copper-bearing rocks of Lake Superior.

B. SILLIMAN: Coals of the Galisteo in New Mexico; Auriferous gravels of the Upper Rio Grande in New Mexico; Los Cerillos, New Mexico, an area of recent eruptive rocks with mineral veins; Note on the Turquois localities of Los Cerillos.

W. J. McGEE: Notes on kames and aasar of N. E. Iowa; On maximum synchronous glaciation.

J. T. HUMPHREYS: Mineral discoveries in Western North Carolina.

T. STERRY HUNT: The genesis of certain iron ores.

W. C. KERR: Ancient topography in North Carolina; Recent geology as illustrated in the coast region of North Carolina; Some points in the structure of mica veins in North Carolina; A new mode of vein formation.

H. A. CUTTING: Capability of the various building stones in general use, to stand heat and water, when hot.

E. S. MORSE: A comparison between the shells of Kjökkenmöddings, and present forms of the same species.

W. O. CROSBY and G. H. BARTON: Extension of the Carboniferous formation in Massachusetts.

C. H. HITCHCOCK: Eruptive rocks of Mt. Ascutney; Occurrence of tin at Winslow, Me.

S. E. WARREN: On an American example of a St. Giles' staircase at Marblehead.

G. F. WATERS: Action of ice on modified drift in Portland, Me.

F. L. CAPEN: The value of the water-shed and water supply of the globe.

J. R. PROCTOR: On the gravel deposits of Kentucky; On several horizons of breccia in Kentucky.

T. EGLESTON: Origin of gold placer deposits and formation of nuggets.

4. *Zoology and Botany, exclusive of Entomology.*

H. ALLEN: Comparative anatomy as a part of the medical curriculum.

A. S. BICKMORE: Improved Stereograph for delineating the outlines of crania.

C. C. MERRIMAN: Microscopic studies in Central Florida.

ELLEN H. WALWORTH: Field work by amateurs.

E. S. MORSE: Notes on Japanese Pulmonifera; Observations on Japanese Brachiopoda.

S. V. CLEVENGER: Plan of the cerebro-spinal nervous system.

B. D. HALDSTED: An investigation of the peach yellows.

P. R. HOY: Menobranchus lateralis.

J. G. HENDERSON: A new craniograph.

L. F. WARD: Incomplete adaptation as illustrated by the history of sex in plants.

B. G. WILDER: Partial revision of the nomenclature of the brain; The foramina of Monro in man and the domestic cat; The *crista fornicis*, a part of the mammalian brain apparently not hitherto described.

T. MEEHAN: Evolution of parasitic plants.

T. TAYLOR: New method of quickening the germination of garden, field, and forest seeds, discovered by the author.

T. J. BERRILL: Anthrax of fruit-trees, or the so-called fire-blight of the pear and twig-blight of the apple-tree.

C. V. RILEY: Further notes on the pollination of Yucca, and on Pronuba and Prodoxus.

W. A. BUCKHOUT: Contribution to the life-history of the Phitoptidæ.

G. MACLOSKIE: The endo-cranium and maxillary suspensorium of the bee.

C. S. MINOT: Anatomy of the tongue in snakes and other reptiles, and in birds—exhibition of sections; On the summation of muscular contractions; Notice of a complete bibliography on Plathelminths.

E. D. COPE: Origin and succession of Felidæ.

S. H. GAGE: Permanent microscopic preparations of Amphibian blood corpuscles. Permanent microscopic preparations of Plasmodium.

C. V. RILEY: Additional notes on the army worm (*Lucania unipuncta* Haw.)

C. SCALER: Minute anatomy of the human larynx.

S. P. SHARPLES: Some of the Infusoria found in Fresh ponds, Cambridge, Mass.

C. W. SMILEY: The Spanish Mackerel and its artificial propagation.

C. J. BLAKE: Occurrence of exostoses in the external auditory canal in prehistoric man.

E. B. WILSON: The metamorphosis of Actinotrocha.

W. K. BROOKS: Notes on the Medusæ of Beaufort, N. C.; The rhythmical character of segmentation.

C. V. RILEY: Recent practical results of the cotton worm inquiry by the U. S. Entomological Commission.

E. CUTTER: Contribution to the histological nature of the membrane in croup; Abundance of microscopic forms of life in the central and lateral surfaces of lakes and ponds.

R R. HOY: Occurrence of *Aletia argillacea* in Wisconsin.

4A. *Entomology.*

C. F. GISSLER: Sub-elytral air passages in Coleopetra.

A. J. COOKE: Two new methods of fighting injurious insects.

W. W. WHEILDON: Brief remarks on the mechanical ingenuity of the house-spider, and the habits of the house fly.

C. H. FERNALD: Method of preparing and mounting wings of microlepidoptera.

B. F. MANN: The contributions of the Cambridge Entomological Club to the progress of entomology.

W. H. SEAMAN: A method of mounting in glycerine and certain differentiations of structure produced by it on insects.

C. V. RILEY: The life-habits of certain bee-flies (Bombyliidæ); Remarks on tree-crickets; Remarks on the curious stages of Blephorocera.

H. A. HAGEN: On biological collections of insects: On some very rare insect deformities.

D. S. MARTIN: Insects from copal.

A. S. PACKARD, Jr.: Migrations of Rocky Mountain locusts.

E. L. MARK: Some points in the anatomy of the Coccidæ.

H. F. BASSETT: Structure and development of certain hymenopterous galls.

J. L. LECONTE: An essay on lightning beetles: List of Coleoptera hatched from a few hickory twigs.

H. C. MCCOOK: The honey-ants of the Garden of the Gods, Colorado.

G. D. PUTNAM: Notes on N. A. Galeodes.

A. R. GROTE: Generic characters of the Noctuidæ.

C. H. FERNALD: On the classification of the Tortricidæ; On Phocopteris angulifascina.

H. A. HAGEN: On the Hessian fly; On the anatomy of Prodoxus decipens.

E. BURGESS: On the structure of the mouth organs in the Lepidoptera.

S. H. SCUDDER: Annual address of the President of the Entomological Club of A. A. A. S.

5. *Anthropology.*

H. B. CARRINGTON: The Dacotah tribes.

A. S. BICKMORE: Ethnology of Africa, illustrated by a large manuscript map.

A. KOCSIS: The Voguls.

W. C. HOLBROOK: Prehistoric altars of Whiteside County, Illinois.

C. F. WILLIAMS: Parturition in a kneeling posture, as practiced by the women of the moundbuilder and stone-grave race.

E. S. MORSE: Persistance of Korean ornamentation in Japanese pottery; Prehistoric and early types of Japanese pottery.

E. A. SMITH: Folk lore of the Iroquois.

J. M. CURRIER: Antiquities in the town of New Haven, Vermont.

D. W. ROSS: Theory of primitive democracy in the Alps.

G. MALLERY: Scheme of the tenth census for obtaining statistics of untaxed Indians.

C. C. ABBOTT: Exhibition of stone implements from the river drift of New Jersey; Indications of a pre-Indian occupancy of the Atlantic coast of North America, subsequent to that of palæolithic man.

J. G. HENDERSON: Textile fabrics of the ancient inhabitants of the Mississippi valley—Pt. I, Material—preparation of material and spinning; Part II, The loom and the fruit of the loom; Pt. III, Moundbuilder, stone-grave and cave fabrics; ancient mounds in vicinity of Naples, Illinois; Sign language and pantomimic dances among the North American Indians.

F. W. PUTNAM: Conventionalism in ornamentation of ancient American pottery; On the occurrence in New England of carvings by the Indians of the Northwest coast of America.

R. J. FARQUHARSON: The probable existence in America of the pre-historic practice of trepanning, in the cutting of rondelles or amulets from the skull; Contemporaneous existence of mastodon and man in America.

GEO. H. PERKINS: Relation of the archæology of Vermont to that of the adjacent states.

WM. MCADAMS: The pipes of the mound-builders and pottery-makers; Ancient agricultural implements of stone; A stone implement, from the base of the drift in Illinois; Sea-shells in the mounds; The mounds of Illinois.

W. J. KNOLTON: Engraved tablet from a mound in Ohio.

W. M. BEAUCHAMB: Antiquities of Onondaga County, New York.

J. F. EVERHART: Ethnology.

D. A. LYLE: The Indian question.

S. S. HALDEMAN: Remarks on aboriginal pottery; On stone axes.

H. C. HOVEY: Alabaster quarries, flint mines and other antiquities recently found in Mammoth, Wyandot and Luray Caverns.

Miss ERMINNIE A. SMITH: On the Iroquois languages.

J. W. POWELL: On the rank of Indian languages: The classification of kindred by the N. A. Indians.

S. D. PEET: The topographical survey of the works at Aztalan, Wis.; The military system of the emblematic mound-builders.

H. C. LEWIS: The antiquity of man in Eastern America geologically considered.

6. *Miscellaneous.*

P. H. DUDLEY: Transportation expenses and their reduction.

GEO. M. STERNBERG: Microscopical investigations of the Havana Yellow Fever Commission.

G. B. GOODE: The first decade of the U. S. Fish Commission. Its plan of work and accomplished results, scientific and economical.

C. ROOSEVELT: Investigations for rapid and safe locomotion.

O. J. BLAKE: Phonophobia and the influence of noise on the health of dwellers in cities.

B. S. HEDRICK: On patent laws as means for the advancement of science.

L. F. WARD: Feeling and function as factors in human development.

E. B. ELLIOTT: The credit of the United States Government.

WM. MCMURTRIE: On the deficiency of meteorological work in data of value to agriculture and means for supplying them.

F. L. CAPEN: Explanation of diagram for 24 hours London and Boston time, showing the method of obtaining formulas for weather prediction.

R. H. DUDLEY: Railroad time service.

A. J. COOK: Contributions of apiculture to science.

4. *Report of the Superintendent of the United States Coast Survey*, showing the progress of the work for the fiscal year ending with June, 1876. 418 pp. 4to, with 24 maps. Washington, 1879.—Among the various memoirs inserted as appendices to this Report, there are the following: A new system of binary arithmetic, by B. PEIRCE; Methods of registering tidal observations with illustrations, by R. S. AVERY; Report on the physical survey of New York harbor, 1876; Note on the theory of economy in research, by Assistant C. S. PEIRCE; Measurement of gravity at initial stations in America and Europe; Comparison of the methods of determining heights by leveling, vertical angles, and barometer, by G. DAVIDSON and C. A. SCHOTT; Observations on atmospheric refraction, and hypsometric formulæ based on thermodynamic principles, by C. A. SCHOTT; and a chart of the magnetic declination in the United States, by C. A. SCHOTT. There is also a list of publications relating to the deep sea investigations carried on in the vicinity of the coast of the United States under the auspices of the Coast Survey, which commences with observations by Count Pourtalés in the year 1850.

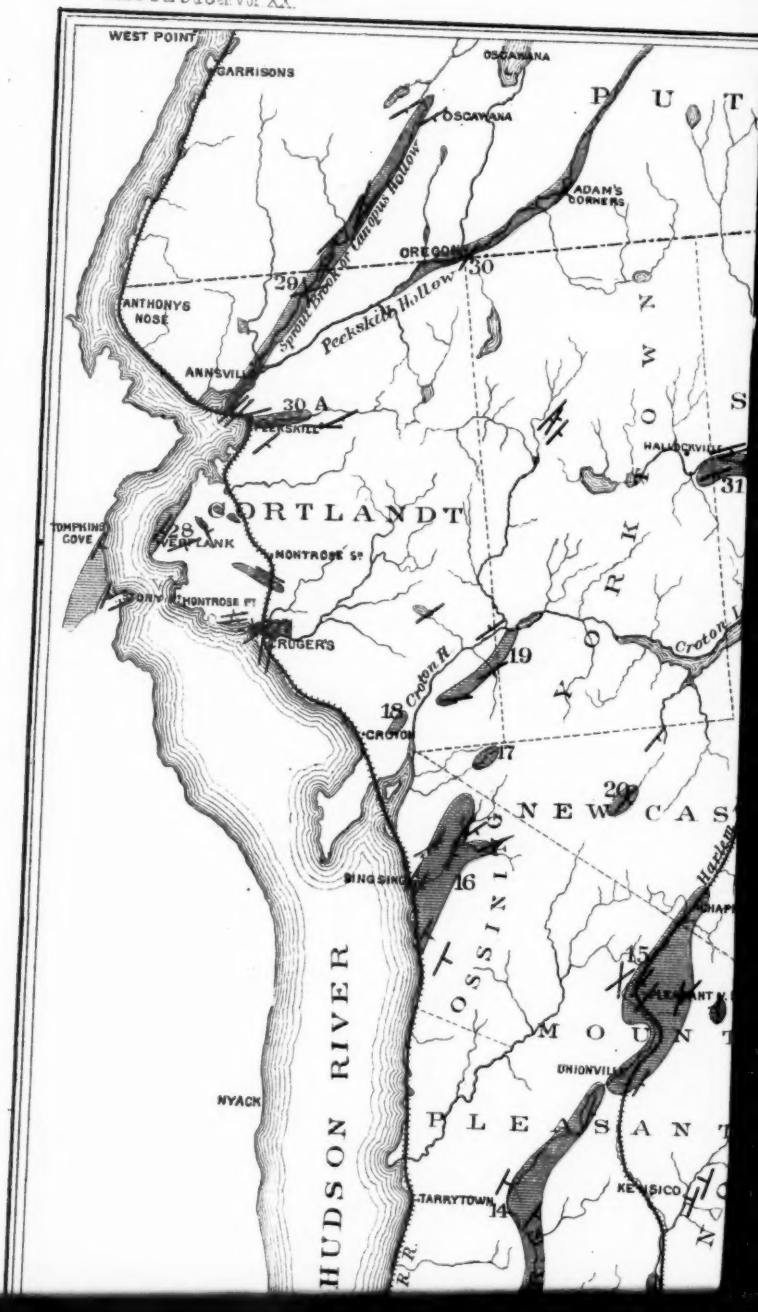
5. *On Spodumene and the results of its alteration from Branchville, Ct.;* by G. J. BRUSH and E. S. DANA: note to the article on p. 257.—The sections represented in figs. 15 and 16 (p. 264), figs. 17 and 18 (p. 265), and 19 (p. 270), are magnified 300 diameters.

OBITUARY.

CHARLES THOMAS JACKSON, early eminent as a chemist, mineralogist, geological explorer and teacher, and long identified with the science of Boston, died on the 29th of August last, at Summerville, Mass. Dr. Jackson was born in Plymouth, Mass., June 21, 1805. While yet a student of medicine in Harvard University, Jackson prepared, in connection with the late Francis Alger, of Boston, a new geological and mineralogical map of Nova Scotia, which was published in the Memoirs of the American Academy at Boston. He subsequently studied science in Paris, under the

most eminent masters, and retained the warm personal friendship of Elie de Beaumont, throughout life. Returning to America in 1832 he soon abandoned medical practice and devoted his energies and talents, with great enthusiasm, to the prosecution of science. He opened the first chemical laboratory in the United States for the instruction of students in mineral analysis, and there some of our leading chemists had their earliest laboratory experience. He became the director of the earliest geological explorations in Lake Superior, and of the geological surveys of Rhode Island and Maine. His controversy with Morse, for the prior invention of the electro-magnetic telegraph, is well remembered, and the more acrimonious one on the subject of etherial anesthesia will probably never be settled to the satisfaction of the friends of either Jackson or Morton. The French Academy, after an investigation, decreed a prize of 2,500 francs to each of the contestants. In the catalogue of the Royal Society there are sixty-nine titles under Dr. Jackson's name, prior to 1863, and his name is found often as a contributor to the early volumes of this Journal. The older chemists will remember his powerful blast-lamp for alkaline fusions, which did good service before the introduction of street gas became general in laboratories. He was an active member, and long the president, of the Boston Society of Natural History. B. S.

Professor Samuel Sherman Haldeman died on Friday, the 17th of September, at his home in Chickies, Pennsylvania, aged sixty-eight years. He was born near Columbia, Pa., in 1812, and graduated at Dickinson College in 1830. In 1836 he was connected with the Geological Survey of New Jersey, and the following year with that of Pennsylvania. He was Professor of Natural History in the University of Pennsylvania from 1851 to 1855, and in 1855 took the same chair in Delaware College, and also that of Professor of Geology and Chemistry in the Agricultural College of Pennsylvania. He afterward became Professor of Philology in the University of Pennsylvania. For many years he worked with great zeal and success in entomology and conchology, and published various memoirs, describing new species and illustrating the broader subject of geographical distribution. Among these are his work on the "Freshwater Mollusca of the United States," his "Zoological Contributions," and a paper on the Coleoptera Longicornia of the United States. Later he devoted himself especially to philological studies, phonetics and orthography. His "Analytic Orthography" obtained for him in England, the Trevelyan prize in 1858. He paid much attention to the Indian languages of North America and their pronunciation. The diversity of his tastes and learning is further shown in his "Tours of a Chess Knight" (1864), a volume of ninety pages illustrated with 114 figures, and containing a bibliography including sixty references.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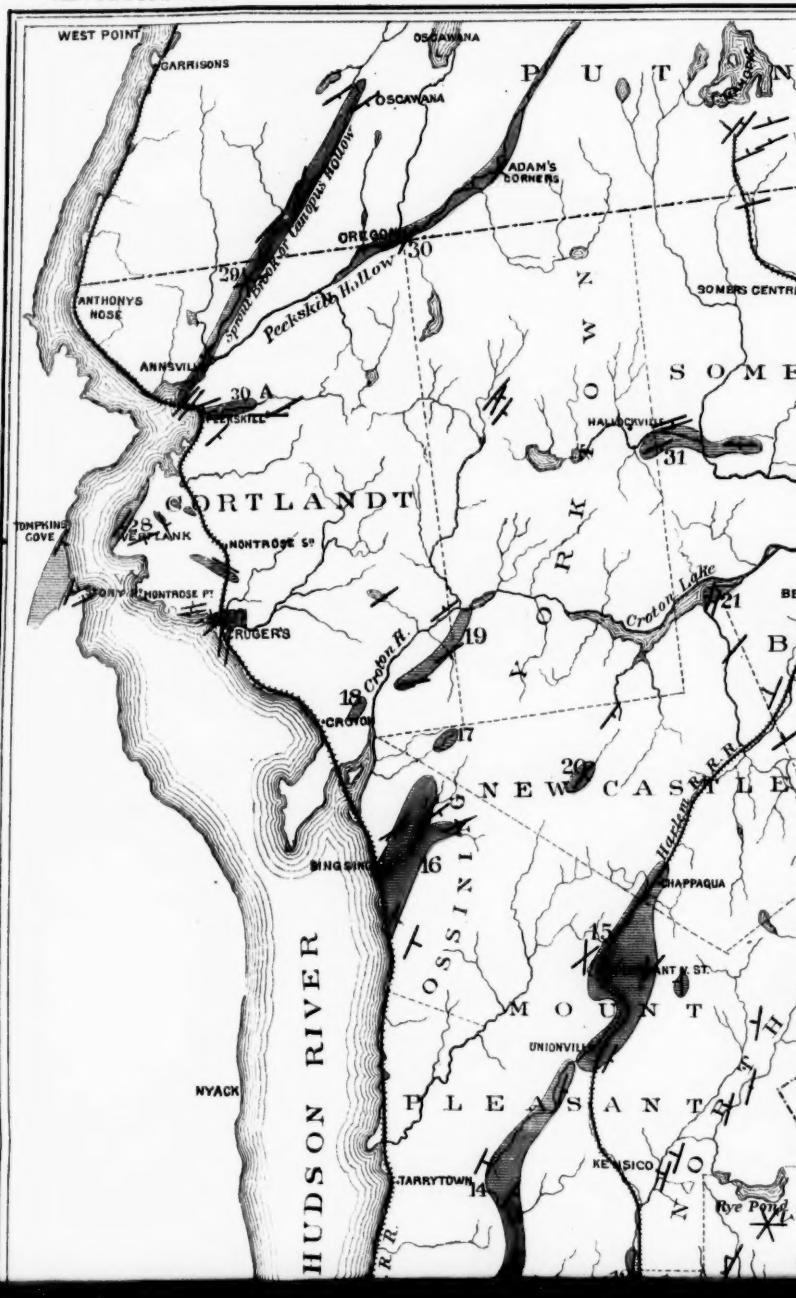
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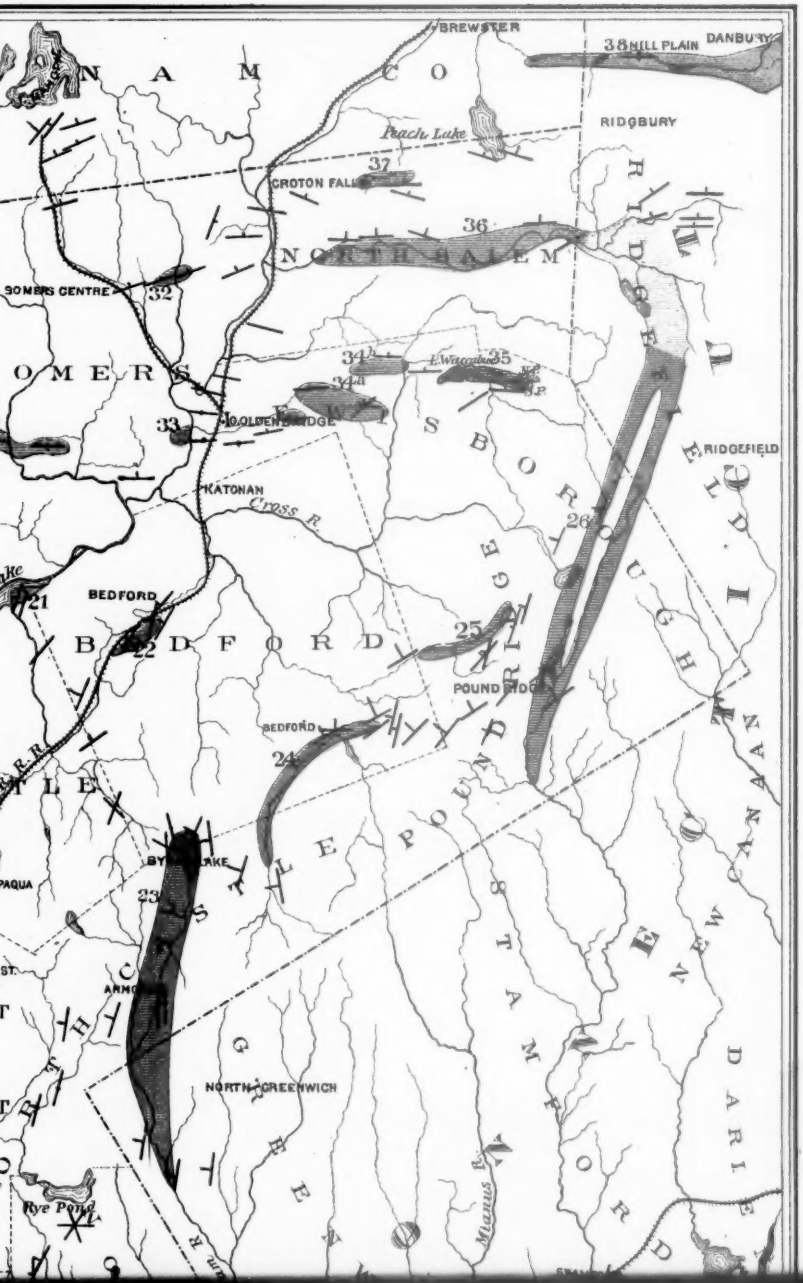
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STAMFORD
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